Microwaves & RF®

RF, COMMUNICATIONS, AND MICROWAVE TECHNOLOGY
AND NEW-PRODUCT COVERAGE—IN DEPTH AND IN CONTEXT

NOVEMBER 2022 mwrf.com

For 5G It's All About CAPACITY

p14

$10.00

NOVEMBER 2022 VOLUME 61, ISSUE 5

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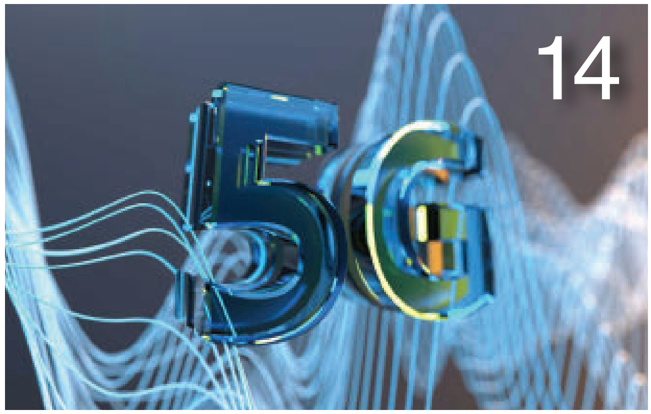

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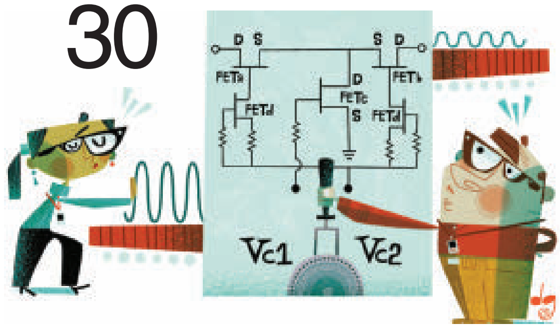

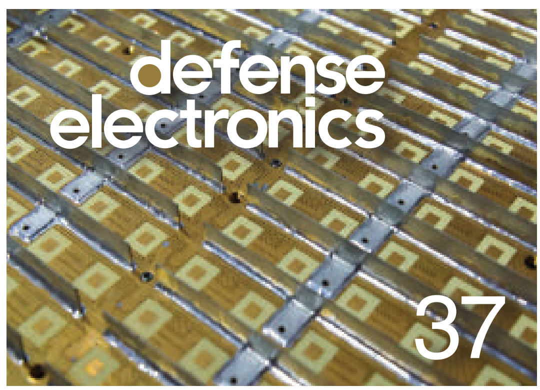

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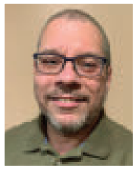

Editorial
DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

A Look Ahead to *Microwaves & RF* in 2023

EARLIER THIS YEAR, my wife received an offer of print magazine subscriptions at insanely low rates. We haven't been subscribing in recent years, and in what was perhaps a minor fit of nostalgia, she ticked a few boxes, thinking it'd be fun to again peruse the pages of publications that cover some of her interests.

But once the magazines began arriving, she quickly realized that they no longer held their appeal from days past. The internet has largely consigned print publications to irrelevance. It's much easier and ultimately more efficient to find things like how-to articles and recipes online and collect bookmarks in folders than it is to flip pages in the hopes that there'll be something worth saving.

In thinking along these lines, we've decided that the print edition of *Microwaves & RF* you now hold in your hands is the last. In 2023, we'll be going to an all-digital format that will allow us to bring you more information organized in more meaningful and useful ways.

In surveying our audience, we've found that you're a digitally savvy and digitally centric crew that uses digital magazines more often than print:

- 21% of you NEVER subscribes to a print magazine.
- 72% reads a digital magazine at least every month, if not more often.
- 35% never attend in-person events while 85% attend virtual events every year.
- 89% engaged with webinar content.
- Search is the highest used tool for information collection (70% responded "important" or "very important") and print is of low value (21% "not important" or "not important at all").

We get it: You value digital content above all else, and we want to make sure our content, and its delivery, reflects your preferences for making fast and informed decisions with limited time and resources.

What do I mean by "more information" in 2023? For starters, we'll alternate each month between digital issues and eBooks. In January, registered site members will receive a wireless test eBook, the first of six planned eBooks for the year. In February, look for the first of six digital issues of *Microwaves & RF*. We'll augment the digital issues and eBooks with several editorial webinars on topics including wireless coexistence, RF amplifiers, consumer technology, and AI in the IoT/IIoT.

As to more meaningful and useful organization of information, content at *www.mwrf.com* is rigorously curated, sliced, and diced into categorizations that span technologies as well as various types of articles.

Of note is our growing collection of TechXchanges. These are digital magazines that house informative articles on topics such as software-defined radio, RFICs and MMICs, defense electronics, and antenna design, to name but a few. Closely related is our repository of TechXchange Talks, comprising short video interviews with industry experts on a wide range of technical topics relevant to your day-to-day work.

All the above is intended to make *Microwaves & RF* more valuable to you. In my September editorial, I noted that consumer electronics is largely driving the growth of the RF components market. That's why in 2023 we'll place more emphasis on consumer-oriented technologies such as Wi-Fi, Bluetooth, ultra-wideband, 5G/6G, and the IoT/IIoT while continuing our broad coverage of important markets such as defense electronics and satellite communications.

Chances are you've heard of Matter, the emerging IoT protocol that will make IoT interoperability really take off in the smart home/office. Technologies like these are propelling the microwave/RF industry forward, and you can count on us to keep you informed in 2023 and beyond. mw

Quantic PMI
PLANAR MONOLITHICS

- Amplifiers - Solid State
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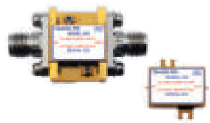
More Limiters available at: https://www.pmi-rf.com/categories/limiters

LM-1G2G-4CW-1KWP-SMF-ROHS
LM-1G2G-4CW-1KWP-SMF
-OPT10M6G

LM-10M9G-100CW-1KWP-SFF



LM-10M35G-15DBM-4W-292FF
LM-10M50G-18DBM-4W-24FF
LM-10M62G-20DBM-1W-24FF

LM-20M18G-100W-15DBM

PMI Model No.	Frequency Range (GHz)	Insertion Loss (dB)	Input Power	Leakage Power (dBm)	Recovery Time	Size (Inches) / Connectors
LM-1G2G-4CW-1KWP-SMF-ROHS	1 -2	0.7	4 W CW, 1 kW Peak 1 µs PW, 1% Duty Cycle	+16	1 µs	1.00" x 0.75" x 0.38" SMA (F/M) Field Removable
LM-1G2G-4CW-1KWP-SMF-OPT10M6G	10 MHz - 6	2.0				
LM-10M9G-100CW-1KWP-SFF	10 MHz - 9	2.0	100 W CW, 10 MHz - 8.0 GHz 80 W CW at 9.0 GHz 50 W CW, 10 MHz - 9.0 GHz 1 kW Peak, 1 µs PW Max, 1% Duty Cycle	+20	100 ns Typ	1.86" x 0.65" x 0.38" SMA (F) Field Removable
LM-10M35G-15DBM-4W-292FF	10 MHz - 35	4.0	Up to 25 W CW & Up to 50 W Peak 1 µs PW, 1% duty cycle	+18	150 ns	0.53" X 0.70" X 0.26" 2.92mm (F) Field Removable and SMT (Drop-In)
LM-10M50G-18DBM-4W-24FF	10 MHz - 50	2.5	4 W CW & 20 W peak, PW 1 µs to 10 µs, 1% duty cycle	+18	100 ns	0.53" X 0.70" X 0.26" 2.4mm (F) Field Removable and SMT (Drop-In)
LM-10M62G-20DBM-1W-24FF	10 MHz - 62	4.0	Up to 1.5 W CW & Up to 10 W Peak 1 µs PW, 1% duty cycle	+22	100 ns	0.53" X 0.70" X 0.26" 2.4mm (F) Field Removable and SMT (Drop-In)
LM-20M18G-100W-15DBM	20 MHz - 18	2.6	100 W CW Max 1 kW Peak Min @ +85 °C 1 µs PW, 0.1% duty cycle	+15	100 ns	0.90" x 0.38" x 0.38" SMA (M) / SMA (F)
LM-150M5G-200CW-2KWPK-AGAL-NFF	0.15 - 5	2.0	200 W CW (+53 dBm) 2 kW Peak (+63 dBm) 25 µs PW, 5% duty cycle	+20	100 ns	1.50" x 1.00" x 1.00" Type N (F) Field Removable
LM-0R3G8G-14-100W-SFF	0.3 - 8	2.2	100 W CW (+50 dBm) +50 dBm Peak, 25 µs PW, 5% duty cycle	+15	100 ns	1.00" x 0.68" x 0.35" SMA (F) Field Removable
LM-1G18G-15-25W-SMF	1 - 18	2.5	25 W CW Max 250 Watts Max 40 µs PW, 10% duty cycle	+15	100 ns	1.00" x 0.68" x 0.35" SMA (F) Field Removable
LM-2G4G-15-100W-SFF	2 - 4	1.5	100 W CW (+50 dBm) 250 W Peak (+54 dBm) 1 ms PW, 10% duty cycle	+21	1 µs	1.00" x 0.68" x 0.35"SMA (F) Field Removable
LM-2G18G-18-20W-1KWP-SFF	2 - 18	2.6	+43 dBm CW +50 dBm 10% DC, 40 µs PW	+18	100 ns	1.00" x 1.00" x 0.40" SMA (F) Field Removable
LM-18G40G-SMT-1	18 - 40	4.0	20 W peak, 440 - 670 ns PW, PRF 600 - 900 kHz, 40% Duty Cycle	+14	250 ns	0.27" x 0.198" x 0.016" surface mount / drop-in carrier

LM-150M5G-200CW-
2KWPK-AGAL-NFF

LM-1G18G-15-25W-SMF

LM-0R3G8G-14-100W-SFF
LM-2G4G-15-100W-SFF

LM-2G18G-18-20W-
1KWP-SFF

LM-18G40G-SMT-1

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West Coast Operation:
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

East Coast Operation:
7309-A Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com

EDITORIAL

Senior Content Director: **Bill Wong**
bwong@endeavorb2b.com

Senior Editor: **David Maliniak**
dmaliniak@endeavorb2b.com

Managing Editor: **Roger Engelke**
rengelke@endeavorb2b.com

Senior Staff Writer: **James Morra**
jmorra@endeavorb2b.com

Technical Editor: **Jack Browne**
jack.browne@citadeleng.com

ART DEPARTMENT

Group Design Director: **Anthony Vitolo**
tvitolo@endeavorb2b.com

Art Director: **Jocelyn Hartzog**
jhartzog@endeavorb2b.com

PRODUCTION

Production Manager: **Brenda Wiley**
bwiley@endeavorb2b.com

Ad Services Manager: **Deanna O'Byrne**
dobyrne@endeavorb2b.com

AUDIENCE MARKETING

User Marketing Manager: **Debbie Brady**
dmbrady@endeavorb2b.com

Article Reprints: *reprints@endeavorb2b.com*

SUBSCRIPTION SERVICES

OMEDA: 847-559-7598 or 877-382-9187
microwaves&rf@omeda.com

LIST RENTAL

List Rentals/Smartreach Client Services Manager:
Mary Ralicki
mralicki@endeavorb2b.com

SALES & MARKETING

Gregory Montgomery
gmontgomery@endeavorb2b.com
AZ, NM, TX

Jamie Allen
jallen@endeavorb2b.com
AL, AR, SOUTHERN CA, CO, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MI, MN, MO, MS, MT, NC, ND, NE, OH, OK, SC, SD, TN, UT, VA, WI, WV, WY, CENTRAL CANADA

Elizabeth Eldridge
eeldridge@endeavorb2b.com
CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, EASTERN CANADA

Stuart Bowen
sbowen@endeavorb2b.com
AK, NORTHERN CA, NV, OR, WA, WESTERN CANADA, AUSTRIA, BELGIUM, FRANCE, GERMANY, LUXEMBURG, NETHERLANDS, PORTUGAL, SCANDINAVIA, SPAIN, SWITZERLAND, UNITED KINGDOM

Diego Casiraghi
diego@casiraghi-adv.com
ITALY

Helen Lai
helen@twoway-com.com
PAN-ASIA

Charles Liu
liu@twoway-com.com
PAN-ASIA

DIGITAL

VP Digital Innovation Data: **Ryan Malec**
rmalec@endeavorb2b.com

DESIGN & ENGINEERING GROUP

EVP, Design & Engineering Group: **Tracy Smith**
tsmith@endeavorb2b.com

Group Content Director: **Michelle Kopier**
mkopier@endeavorb2b.com

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18 Debbie M Brady, Manager User Marketing — Date 9/21/22

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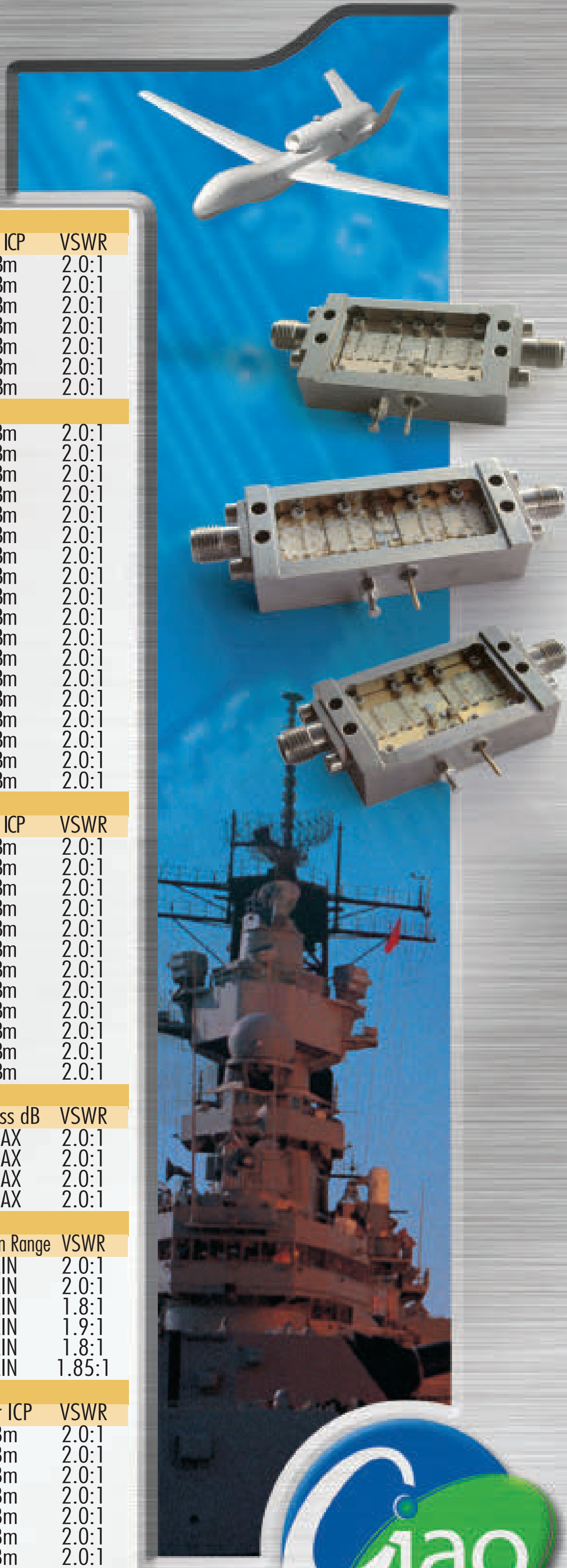

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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News

Silicon Labs Debuts IoT Dev Platforms, SoCs with Focus on Matter 1.0

Complete development support for Matter and Amazon Sidewalk, coupled with SoCs for Wi-SUN and Wi-Fi 6/Bluetooth LE, broaden SiLabs' IoT portfolio.

204911392 © Nicoelnino | Dreamstime.com

The Overview

At its annual Works With Developer Conference, Silicon Labs unveiled:

- A set of complete Matter development solutions with support for Matter over Wi-Fi, Matter over Thread, Bluetooth LE commissioning, and Matter bridges to Zigbee and Z-Wave
- An end-to-end development platform for Amazon Sidewalk
- A flagship SoC and power amplifier for Wi-SUN for dense urban environments
- The company's first Wi-Fi 6 and Bluetooth LE SoC family

Who Needs It & Why?

According to Silicon Labs CEO Matt Johnson, it's estimated that "by 2025, there will be 27 billion connected IoT devices, roughly three or four devices per person on the planet." Many of those devices will connect through the forthcoming Matter 1.0 standard, which promises, through a unifying application layer, to provide the interoperability bridge between multiple smart-home ecosystems.

SiLabs's Series 2 SoC family, which debuted in 2019, was developed under the premise that as the IoT matured, instead of looking for point solutions, the market would seek IoT platforms that combine hardware, software, security, tools, and support. That turned out to have been prescient, and the Series 2 family, with these latest additions, provides a wealth of resources for developers of IoT-enabled devices.

Under the Hood

At the heart of SiLabs' Matter portfolio is its 2.4-GHz wireless MG24 SoC for Bluetooth and multiple-protocol operations. The SoC also supports Matter over Thread as a single-chip solution, while providing an effective indoor range of up to 200 meters for OpenThread and enabling Bluetooth commissioning of new devices on the same chip. When the MG24 is combined with the company's ultra-low-power RS9116 Wi-Fi product, it enables development of Matter over Wi-Fi 4 with an easy transition to Silicon Labs' Wi-Fi 6 single-chip Matter SoC in 2023.

The company's Unify SDK, touted as the only multi-protocol software-development platform for Matter Border Routers, provides the tools to bridge Matter to other IoT platforms, including Zigbee and Z-Wave. Its Simplicity Studio and GSDK provide developers with a single development environment for enabling Matter on wireless devices and seamlessly connecting them to their desired ecosystem.

Development for Amazon Sidewalk

In its Pro Kit for Amazon Sidewalk, SiLabs delivers an end-to-end development platform for Amazon's community network. The Silicon Labs Pro Kit for Amazon Sidewalk comprises low-power, high-performance wireless hardware for all Amazon Sidewalk protocols, including Bluetooth Low Energy, sub-GHz FSK and CSS, software SDKs, and security.

The Silicon Labs Pro Kit for Amazon Sidewalk comes with a pre-flashed software image and AWS pre-registration. This provides developers with a quick start to Amazon Sidewalk development, saving them days in setup. Simplicity Studio, the integrated development environment (IDE) for all Silicon Labs technologies, guides developers through the entire Amazon Sidewalk development journey from start to certifying finalized code into a guided, end-to-end process.

While anyone can develop an Amazon Sidewalk device, Amazon Sidewalk connectivity is currently only available to end consumers and endpoint devices in the U.S. The Silicon Labs Pro Kit for Amazon

Sidewalk is sampling today, with general availability planned for 2H 2023.

A Secure, Long-Range Smart-City Combo

In 2023 and beyond, we'll see a big push toward intelligent, connected devices in cities and other municipal environments. To support those efforts, SiLabs' new FG25 SoC and its complementary EFF01 RF power amplifier serve low-power wide-area networks (LPWANs) like Wi-SUN and other proprietary sub-GHz protocols. The FG25 SoC combines a powerful Arm Cortex-M33 processor with the most internal memory of any SoC in Silicon Labs' portfolio. This large pool of internal memory, combined with Silicon Labs' scalable Wi-SUN Field Area Network (FAN) Border Router 1.1, enables FG25 deployments to scale to hundreds of thousands of nodes.

Ideal for smart cities, this ability to scale will allow city planners and municipal engineers to connect streetlights, cameras, weather stations, smart metering, utility transmission systems, and more together. In turn, it will enable data sharing and optimization between city services to improve their efficiency, save costs, and offer more ways for citizens to interact with, and get more value from, municipal services.

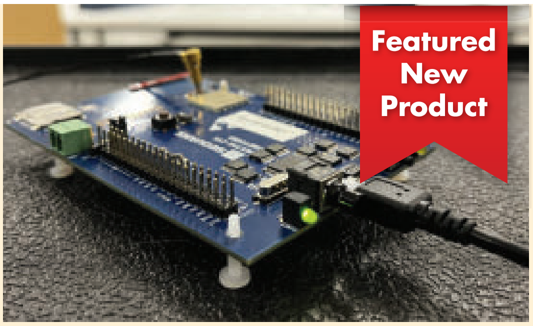
NEW! Video: Matter Gains Traction—and Solutions; https://mwrf.com/21253595

To complement the FG25 SoC, the EFF01 RF front-end module doubles the effective range of the FG25, allowing it to operate with minimal data loss at a range of up to 3 km in dense urban environments. The FG25 and EFF01, currently sampling with customers, are anticipated to become generally available in Q4 2022 and Q2 2023, respectively.

Secure, Ultra-Low-Power Wi-Fi 6

According to Deloitte's "2022 Connectivity and Mobile Trends Survey," the average U.S. household has up to 22 connected

"Power as a Service" Now a Possibility with Cellular-Based Remote RF Charging Platform



Sequans' Monarch 2 GM02S cellular module for IoT connectivity teams with Powercast's RF transmitting antenna to send RF over-the-air to a Powercast PCC110 Powerharvester receiver chip embedded in end devices.

Photos courtesy of Powercast

The Overview

Powercast has created a cellular-based RF power-over-distance wireless-charging platform, built around Sequans' Monarch cellular IoT connectivity technology. The introduction of cellular technology into the over-the-air RF wireless-charging picture creates opportunities for more manufacturers to develop environmentally friendly smart-home IoT ecosystems that eliminate disposable batteries.

Who Needs It & Why?

Operating in the lower 600- to 900-MHz frequency bands licensed by mobile carriers, the Powercast cellular-based RF wireless charging platform offers the following benefits:

- Because cellular bands are licensed, or private, they have more flexibility on how much power they can transmit, on antenna gain, and on bandwidth, which enables end devices to charge faster and at greater distances when compared to unlicensed, or public, bands.
- As cellular service moves increasingly to higher frequencies like 5G to increase data throughput, carriers can monetize their underused low-frequency bands and offer "power as a service."
- Ability to simultaneously charge many consumer devices at-a-distance, such as IoT sensors for smart-home security and automation, TV remotes, keyboards, earbuds, headphones, smart watches, fitness bands, and hearing aids.

Using licensed cellular frequencies to increase device charging power will allow manufacturers to create green, sustainable IoT devices that can charge more quickly

devices, a number that's expected to grow. But with this greater density comes additional challenges that Wi-Fi 6 is designed to address, offering the features that provide the capacity, efficiency, coverage, and performance required by users in demanding Wi-Fi environments.

To meet those challenges, the new secure ultra-low-power SiWx917 Wi-Fi 6 and Bluetooth LE combination SoC is the first Wi-Fi 6 solution in Silicon Labs' portfolio. The SiWx917 is a single-chip solution that is Matter-ready, includes an integrated applications processor, and offers industry-leading energy efficiency, making it ideal for battery-powered or energy-efficient IoT devices with always-on cloud connectivity.

In addition to SiWx917's Wi-Fi 6 support for high-performance in dense wireless environments, it includes a dual-core architecture, a quad-thread ThreadArch processor for wireless connectivity, and an Arm Cortex-M4F for user application processing. It also integrates embedded SRAM, flash, an AI/ML accelerator, an enhanced PSA Level 2 certifiable security engine, and a power-management subsystem in a single 7x7 package.

The SiWx917 is a fully integrated SoC designed to deliver exceptional compute power, faster machine-learning processing, best-in-class security, enough memory to run wireless stacks and applications, and ultra-low current consumption for long battery life. Such features can help users reduce development costs and device footprint, future-proof their applications, and accelerate time-to-market.

The SiWx917 is currently sampling, with general availability anticipated in early Q3 2023. ■

and at longer distances from a cellular RF transmitter, it's claimed.

Under the Hood

The platform combines Sequans' Monarch 2 GM02S module *(see figure)* with a Powercast RF transmitting antenna to send RF over-the-air to a tiny Powercast PCC110 Powerharvester receiver chip embedded in end devices. The Powerharvester harvests RF out of the air and converts it to dc (direct current) to either power a battery-free device, or charge a rechargeable battery, both of which keep disposable batteries out of landfills.

In demos at this week's Mobile World Congress in Barcelona, a Sequans Monarch 2 cellular modem teams with Powercast's 700-MHz antenna to transmit a 700-MHz RF cellular signal to Powercast's PCC110 receiver and RF-to-dc converter chip.That then powers a battery-free sensor beacon to transmit temperature and humidity data to a gateway or phone. ■

Dev Platform Unifies Automotive Wireless Connectivity into Single Domain Controller

The Overview

NXP Semiconductors' OrangeBox automotive-grade development platform integrates a wide variety of wireless technologies, from broadcast radio, Wi-Fi 6, and Bluetooth to secure car access with ultra-wideband (UWB) and Bluetooth Low Energy (BLE), as well as 802.11p-based V2X. The OrangeBox is a single, security-enhanced, modular platform that offers a unified interface between the vehicle's gateway and its wired and wireless technologies. By doing so, it provides a means for next-generation cars to securely communicate with the world around them.

Who Needs It & Why?

More connected than ever, today's cars use an array of wireless technologies to provide drivers and passengers with everything from infotainment to advanced safety features. But with these technologies distributed throughout the vehicle's architecture, multiple development challenges are exacerbated as more and more connectivity features are added, expanding the cyberattack surface.

OrangeBox unifies these current and emerging external wireless interfaces into a single, security-enhanced connectivity domain controller, which then connects to the secure vehicle gateway through NXP's high-speed Ethernet silicon. This consolidated, turnkey approach reduces development effort and optimizes the movement of data across multiple communication interfaces. It also enables consistent, state-of-the-art security protection to be applied to all traffic entering the car and eases the deployment of V2X and cloud applications, such as over-the-air updates for software-defined vehicles.

Designed as a modular platform, OrangeBox provides OEMs and Tier-1 automotive suppliers with the flexibility to adapt to various regional requirements for cellular connectivity and V2X, as well as enable in-field updates necessary to keep up with changing technologies. This helps accelerate time-to-market, reduces complexity, and provides a complete system reference design ready for application deployment.

Under the Hood

The OrangeBox development platform integrates leading NXP technologies, including an advanced applications processor, a software-defined broadcast radio tuner, Wi-Fi 6, and Bluetooth. It also features secure car access with BLE and UWB, as well as 802.11p-based V2X, both secured by the company's certified EdgeLock discrete secure elements. Support for 4G LTE or 5G cellular and GPS connectivity is in the mix, too.

The platform makes it simpler for automakers to consistently apply state-of-the-art cloud-managed security technologies, such as next-generation firewalls, to data traffic entering or leaving the vehicle. The central processor of the OrangeBox is an i.MX 8XLite applications processor running a unified Linux-based software platform to manage the automotive wireless connectivity. It includes a Gigabit Ethernet connection to the central vehicle gateway, allowing other automotive systems to leverage the benefits of integrated wireless connectivity more easily.

The OrangeBox automotive development platform is expected to be available to customers in 1H 2023. ■

EVERY BLOCK...
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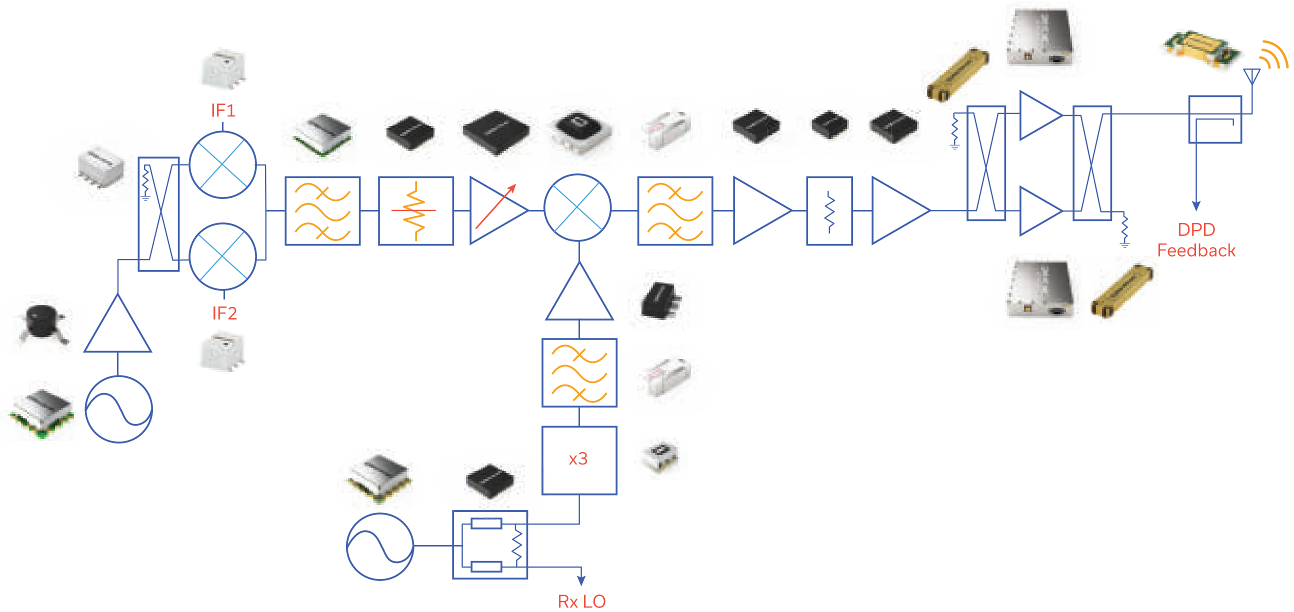

LTCC Passives
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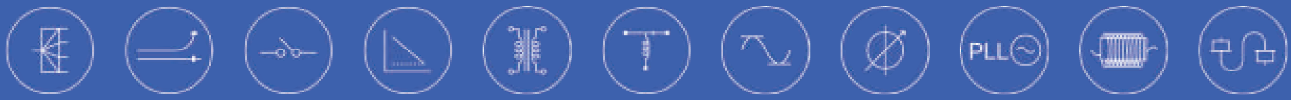
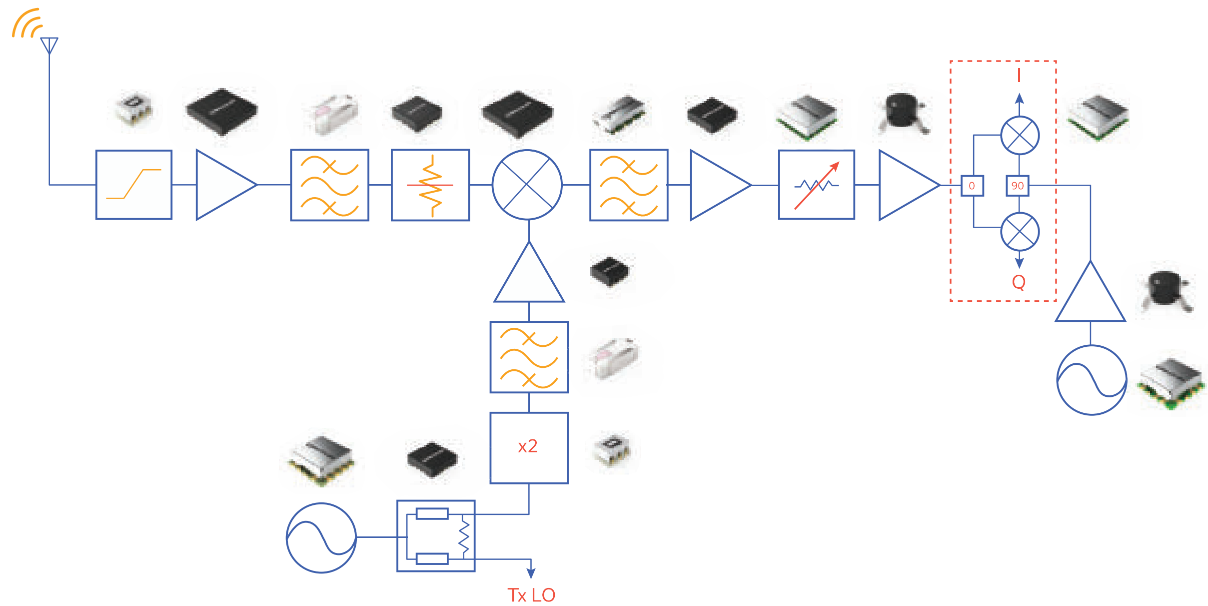
- **Reflectionless Filters**: Passbands to 40 GHz

AND MORE



The Industry's Broadest Technology Portfolio From DC to mmWave



Magnetic Core & Wire

10k+ Models

- **Directional Couplers**: 1 MHz to 6 GHz
- **Power Splitters**: DC to 18 GHz
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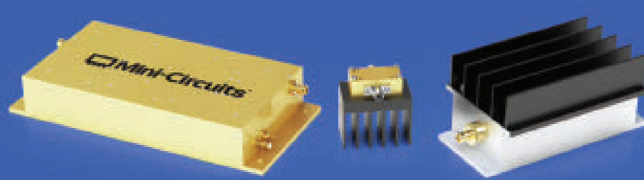


Amplifier Modules

270+ Models

- **Power**: Up to 250W
- **Medium Power**: Up to 95 GHz
- **Low Noise**: Up to 85 GHz
- **Low Phase Noise**: -173 dBc/Hz @ 10kHz

FRANCK NICHOLLS | Head of Commercial Marketing, RF Power, NXP Semiconductors

5G Densification: Making 5G a Working Reality

With 5G cellular forging ahead, understanding the economics behind the investment decisions is crucial to overcoming complexities around deploying 5G.

Dreamstime | Jackymkleung 194674995

As the rollout for 5G cellular continues, network operators are modifying the existing infrastructure. They're adding what's needed to support the higher rates, greater device density, and lower latency we'll need to run advanced 5G use cases, now and in the future.

Operators have done this kind of work before, moving cellular from 2G to 3G and 4G, but this time it's different. 5G is more than just an overlay on the previous generation—it's a seismic shift that brings fundamental change at every level. Preparing for 5G operation means having to deal with new technologies and new techniques, from recently opened bands of unfamiliar spectrum and complex active antenna architectures to virtualization and machine-learning algorithms.

At the same time, the goal of infrastructure investment has taken a turn. The traditional focus, in place for roughly 30 years, has been on coverage and trying to find the lowest cost per square kilometer serviced. The focus for 5G, on the other hand, is on capacity, and trying to find the lowest cost per gigabit delivered.

As the network is becoming denser, with more pieces of equipment used to provide 5G capacity within a given area, it's also becoming more diverse—more types of equipment are used to deliver 5G service. What was once a network dominated by traditional macrocells is becoming an intricate mix of technologies used to deliver capacity where it's needed most.

The complexities of deploying this kind of heterogeneous network are offset by the fact that the cellular service becomes more flexible, making it easier to meet changes in demand and support new use cases while managing costs. To understand the economics of these investment decisions, it's useful to review what makes 5G different and, as a result, more challenging to work with.

Three Ways 5G is Different

Three things that set 5G apart from previous generations are 1) where in the wireless spectrum it operates; 2) the antenna structure used to transmit and receive signals; and 3) the transition to a more software-based approach to managing and optimizing operation.

- *New spectrum:* As shown in *Figure 1*, 5G extends the existing cellular spectrum to include the area between 2.7 and 6 GHz and adds a completely new part of the spectrum above 25 GHz. This new portion of the spectrum, known as millimeter wave (mmWave), was previously reserved for other services, such as medical imaging, microwave remote sensing, amateur radio, terahertz computing, and radio astronomy. It will enable ultra-high bandwidth and ultra-low latency use cases but presents a steep learning curve for engineers used to working below 6 GHz.
- *New antenna configurations:* 5G uses active antennas, which are more highly integrated and more complex than the passive antennas traditionally associated with cellular. Active antennas require a sophisticated

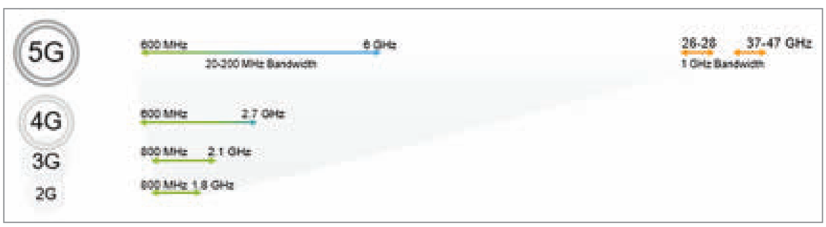
mix of hardware and software and leverage massive MIMO (mMIMO), a technique that involves dozens (if not hundreds) of antennas working together to expand capacity within the same bandwidth. Working with so many antennas is a complex, compute-intensive task that requires careful optimization to ensure reliable, interference-free operation.

- *More code:* 5G makes extensive use of virtualization, with more being done in the cloud, and often uses machine-learning (ML) algorithms for optimized network management, orchestration in the core, traffic monitoring, and load balancing. A typical 5G base station has millions of lines of code, using software to add new features like support for more devices, increased capacity, and expanded coverage to accommodate more traffic. Heavy reliance on software changes how the network is deployed and operated and changes the security models.

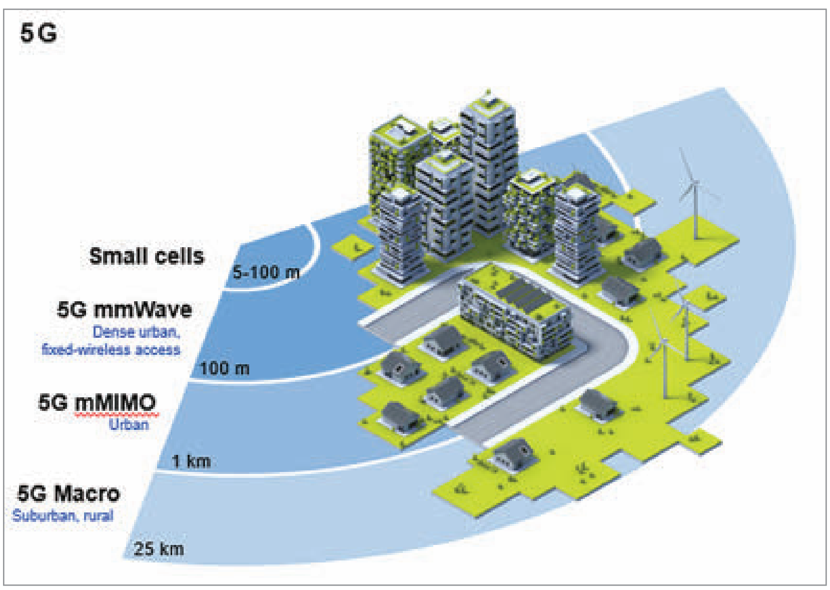
Putting 5G to Work in Layers

Preparing the infrastructure for 5G operation, through what's known as 5G densification, involves adding different layers of coverage, each providing the throughput improvements needed for a given area or use case. As shown in *Figure 2*, these layers consist of traditional 5G macrocells, 5G mMIMO cells, 5G mmWave cells, and small cells.

- *Traditional 5G macrocells:* Serving a wide area of about 25 km, traditional 5G macrocells mainly provide capacity in suburban and rural environments. Like their 4G counterparts, traditional 5G macrocells are big, high-powered base stations that live on towers, monopoles, and rooftops, and are sometimes made to look like giant trees. They typically use a passive antenna system and a simple multiple-input, multiple-output (MIMO) configuration for transmission and reception that employs either four antennas (4T4R) or eight antennas (8T8R) driven at 40 W.
- *5G mMIMO cells:* Serving a smaller area of about 1 km, 5G mMIMO cells are used to provide capacity in urban environments that have a higher device density than suburban and rural areas. The traditional macrocell's passive antenna and radio unit are replaced with an active antenna system. The active antenna system combines mMIMO configurations with other 5G features, such as beamforming, to increase throughput while reducing interference. Typical configurations use 32 antennas (32T32R) driven at 10 W or 64 antennas (64T64R) driven at 5 W.
- *5G mmWave cells:* Serving an area of about 100 m, 5G mmWave cells use the new spectrum above 25 GHz to provide capacity in urban environments with very high device density as well as support fixed wireless access (FWA) in buildings. Working in the mmWave spectrum means exceptionally high bandwidth, made possible by using hundreds of antennas in a mMIMO configuration (e.g., 256R256T) driven at 200 mW. However, because mmWave signals have a lower wavelength, they don't travel as far. To balance the tradeoff between bandwidth and power consumption, 5G mmWave cells have limited range.
- *5G small cells:* Serving an area of between 5 and 100 m, 5G small cells are backpack-sized, low-power base stations that provide targeted capacity in network "hotspots." Small cells are compact and lightweight, so they can be mounted just about anywhere. They prevent 5G signals from being



1. 5G adds new frequency spectrum, including the area between 2.7 and 6 GHz and a completely new part above 25 GHz. *NXP Semiconductors*



2. 5G densification brings capacity in layers. *NXP Semiconductors*

dropped in crowded areas, such as city centers or sports venues. A 5G small cell is, in many ways, a miniature, low-power version of a traditional 5G macrocell. It typically uses a passive antenna with a smaller MIMO setup of just four antennas (4T4R), but driven by a much lower power of just 1 W.

Finding the Right Mix

The layered approach takes advantage of the fact that 5G is a standard that meets many different requirements. It also lets operators tailor network operation to meet specific needs while keeping costs in check.

A single operator might, for example, use 2T2R or 8T8R macrocells to service rural and suburban areas, while using 32T32R or 64T64R mMIMO cells to service semi-dense urban areas and dense urban areas with tall buildings. The higher cost of mmWave can be saved for the areas with the highest densities, such as a crowded business district, an international shipping port, or an entertainment venue that hosts major sporting and cultural events.

A Work in Progress

Completing the process of 5G densification will take time. The 5G networks already in place today mostly leverage legacy 4G networks, in what's called a non-standalone (NSA) network setup. The 5G capability is essentially anchored to 4G, so that users can back off an LTE connection when a 5G connection is unavailable.

Before 5G becomes widely available, mMIMO can be used to increase LTE speeds and improve latency. However, the real benefit of mMIMO, and its positive effect on network density, will kick in once the infrastructure transitions to the standalone (SA) setup, which is a pure 5G network for higher-frequency operation.

The transition to SA networks will help drive uptake of mMIMO and accelerate 5G densification. ABI Research, in its February 2021 report on network infrastructures, calculated that the installed base mMIMO market is expected to grow at a compound annual growth rate (CAGR) of 63.8% between 2020 and 2026 to reach \$58.2 billion by 2026. The Asia-Pacific market will be particularly strong, with MNOs expected to deploy 28.3 million units—more than 78% of the total mMIMO market—by 2026.

5G and Wi-Fi 6/6E

While cellular networks have been evolving toward 5G, Wi-Fi networks also have been evolving to the next generation. Known as Wi-Fi 6/6E, the latest versions of Wi-Fi bring the high-throughput and low-latency benefits of 5G to the indoor environment and are much easier to deploy than 5G. Chipsets for Wi-Fi 6, which runs in the licensed 2.5- and 5-GHz spectrum, and Wi-Fi 6E, which runs in the unlicensed 6-GHz spectrum, are already available.

Cellular and Wi-Fi are complementary technologies. Today's smartphones already combine the two, making it possible to switch from cellular to Wi-Fi when the cell signal is weak or to save on data usage. This trend is expected to continue, with Wi-Fi 6/6E and 5G small cells working in tandem to support more devices accessing more data, all at once.

5G can even boost the deployment of Wi-Fi 6/6E by making it easier to connect Wi-Fi signals to the core network.

5G can even boost the deployment of Wi-Fi 6/6E by making it easier to connect Wi-Fi signals to the core network. In FWA applications, for example, 5G mmWave cells can be used as the backhaul service, replacing the expensive fiber-optic cabling currently used to link many Wi-Fi gateways to the core network.

5G isn't a one-size-fits-all proposition. From power amplifiers, high-power transistors, beamforming ICs, and highly integrated receiver and driver modules to power-efficient Arm processors and customizable, DSP-driven baseband devices, the right components make the 5G infrastructure more efficient, more effective, and more reliable.

BRENDON MCHUGH | Field Application Engineer & Technical Writer, Per Vices Corp.

SDR vs. RFSoC: What's the Better Transceiver?

Software-defined radio or radio-frequency system-on-chip? This article compares the two technologies and weighs their advantages and disadvantages for different connectivity applications.

Transceiver devices are ubiquitous in today's highly connected world. Various transceivers exist for a wide range of applicability, which often combine analog, digital, and mixed-signal components. This article focuses on software-defined radio (SDR), radio-frequency system-on-chip (RFSoC/SoC), and digital front-end (DFE) technologies, all of which work as transceiver devices with embedded digital-signal-processing (DSP) capabilities.

Discussed are the advantages/disadvantages of using an SDR with discrete integrated circuits (ICs) and other components for the analog domain, as opposed to RFSoC/SoC (or other fully embedded radio front ends).

Basics of SDR

An SDR is a highly flexible transceiver platform consisting primarily of a radio front end (RFE), mixed-signal interfaces, and processing support in the digital backend *(Fig. 1)*. High-performance SDRs are critical for many wireless applications and tend to have more analog circuitry and are more easily integrated into RF systems compared to the RFSoC/DFE transceivers we're discussing.

The SDR itself contains an RFE with receive (Rx) and transmit (Tx) functions to handle signals over a wide tuning range, which is accomplished using various mixing stages in both analog and digital. In addition, these radio chains offer very high bandwidths of up to 3 GHz per radio chain and up to 16 fully independent radio chains per SDR.

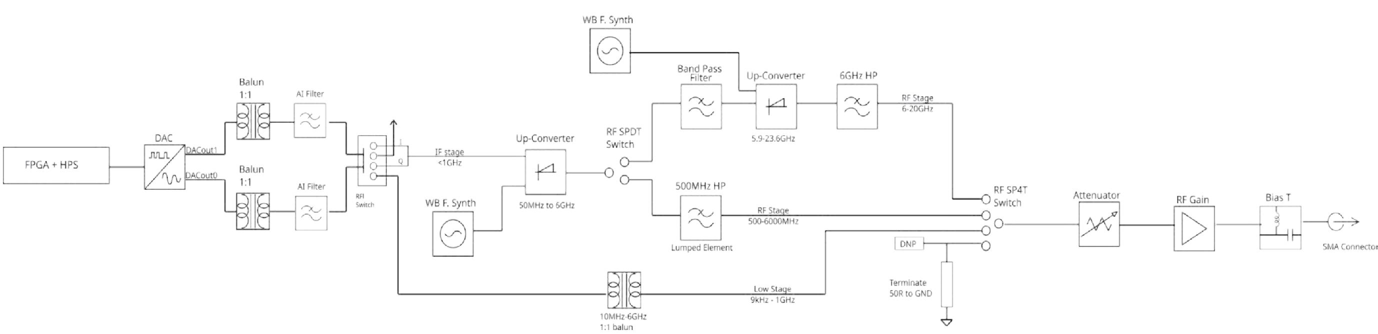
The SDR's digital backend contains a high-performance Arm CPU/FPGA with onboard DSP capabilities for modulation, demodulation, digital upconversion (DUC), digital downconversion (DDC), filtering, etc. Furthermore, SDRs are highly reconfigurable and upgradable to the latest radio protocols, DSP algorithms, IP cores, etc.

The FPGA also contains the means to packetize data into Ethernet packets and transport it over SFP+/qSFP+ links over 10- to 100-Gb/s links. These devices come with an API to develop/control the radio system via a host system, as well as signal-processing development toolkits such as GNU Radio.

Basics of RFSoC

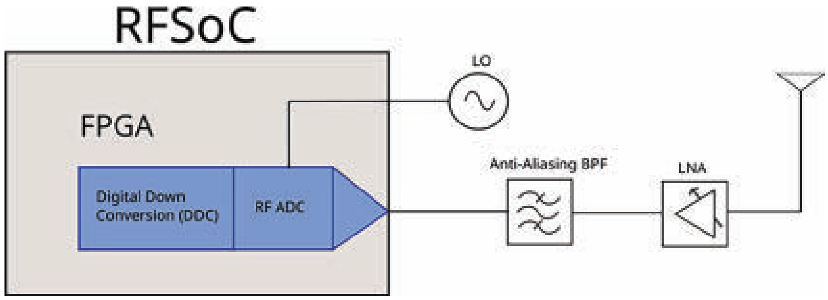
Traditional system-on-chip (SoC) technologies were designed specifically for their use case, such as Bluetooth, Zigbee, Wi-Fi, and even mobile-phone chips (GPS, etc.), all of which were reduced to a small-scale transceiver design. As with most electronics, size has decreased while functionality is on the rise, as can be seen in one of the latest developments in transceivers—the RF system-on-chip (RFSoC). These transceivers or fully integrated SoC dedicated chips were developed by Xilinx and premiered in 2017.

In particular, RFSoC devices essentially embed RF-class multichannel analog-to-digital converters (ADCs) and digital-to-analog converters (DACs)



1. Shown is a software-defined radio transceiver architecture with multiple stages (a simplified version of Per Vices' Cyan Tx board). *Per Vices*

with Xilinx's multiprocessor system-on-chip (MPSoC) as well as an Arm processor enhanced FPGA. As shown in *Figure 2*, the architecture integrates the mixed-signal's interface (ADC/DAC) into the signal chain. These devices use a direct-sampling ADC/DAC with DDC and DUC.



2. The diagram illustrates the receiver (Rx) RFSoC transceiver architecture.

Pros and Cons of RFSoCs

A significant benefit of RFSoCs is their lower power consumption. The driving factor behind the reduced power of RFSoCs is the need for fewer boards, and the elimination of the interfaces required to connect the various ICs in a discrete solution.

One such common serial interface standard is JESD204B, which has been eliminated from the Xilinx RFSoC product line. With the RFSoC, data converters are integrated directly into the FPGA using parallel interfaces, and thus, these devices don't require the high-pin-count external connections needed for discrete parallel interface converters.

In addition, RFSoCs don't have the latency associated with a JESD204 serial interface. This makes them an attractive solution for low-power, multichannel-count, and low-latency applications. Cost-effectiveness also is a benefit of SoC transceivers in applications requiring limited functionality, which as mentioned, are integrated on a single chip. In these applications, RFSoC devices need only a few support circuits, such as a microprocessor for control, a power supply, and an antenna(s).

While RFSoC devices are impressive and can be advantageous in a number of applications, they also have multiple disadvantages. As RFSoCs/DFEs are essentially chips with embedded direct-sampling data converters, an engineer often needs to design a printed circuit board (PCB) around the RFSoC to increase capabilities as well as house the boards in some sort of enclosure (for environmental or ruggedization, for instance). Such a dense design of data-converter interfaces creates many challenges.

For starters, numerous issues exist when it comes to signal integrity on the RFSoC, including spurious digital-signal pickups, crosstalk between channels, matters related to impedance matching, and issues of thermal management. Much of this can't be avoided, particularly at higher frequencies where these effects are more visible. That's why the most sophisticated RFSoCs currently on the market only have tuning ranges up to 7.1 GHz.

There's lots of flexibility when you build out your entire radio chain using discrete commercial off-the-shelf (COTS) ICs (amplifiers, filters, attenuators, mixers, etc.) that can be optimized for particular RF performance requirements.

Moreover, the timing and synchronization between new board components (PLLs, NCOs, LOs, etc.) will all need to be integrated with the RFSoC, where timing/alignment is only considered in the digital domain. However, the PCB layout must be designed to consider the latency requirements of the RFSoC.

Many challenges also crop up when developing the FPGA "firmware" code for the RFSoC/SoC/DFEs, because you need to be widely familiar with programming in hardware descriptive language (HDL), plus various other embedded-system design programming, to have a functional radio/DSP system. For instance, if you're trying to design a custom modem, implement some sort of packetization standard (i.e., to transfer data over Ethernet in VITA 49 packets), or develop a custom signal processor, a lot of development time will be required.

Pros and Cons of SDRs

As can be gathered from the discussion on RFSoCs, lots of development is usually required to get a functional wireless technology up and running. Thus, an already-developed SDR (i.e., has an API, works with DSP development toolkits, already passes data from the transceiver to a host-system-computer/storage devices, uses VITA 49 packet formats, etc.) can significantly reduce time-to-market or setup for a particular application.

For SDR manufacturers that use a dedicated analog RFE, the possibility remains to build custom designs that entail many performance benefits. There's lots of flexibility when you build out your entire radio chain using discrete commercial off-the-shelf (COTS) ICs (amplifiers, filters, attenuators, mixers, etc.) that can be optimized for particular RF performance requirements.

For instance, the RFE can be customized for various performance requirements (tuning range, elimination of spurs within a band, output power, etc.). Another advantage of using an SDR with discrete components is that you can bypass numerous components in the RFE, which isn't possible with RFSoCs. On top of that, the SDR's RFE allows for higher tuning

ranges (due to multiple mixer stages/multiple RFE signal chains). And in certain applications, it's often possible to design an SDR that conforms to a particular size, weight, and power (SWaP) specification.

In terms of FPGA resources, on high-performance SDRs like Per Vices' Cyan platform, there are many more logic elements/cells. These SDRs contain 5.5 million logic elements compared to the maximum of 930,000 currently available on RFSoC. Also, when working with an SDR manufacturer, it becomes possible to implement custom HDL code in a much less time-consuming and cost-effective manner compared to having to develop in-house.

The ease of use is worth mentioning, too. With most SDRs, data from the FPGA is passed over qSFP+ ports to a host system that has a number of different UIs to control the actual radio (for instance, with GNU Radio, Web UIs) and maintains compatibility with UHD for development in C++, GNU Radio, or Python.

Thus, when using or integrating an SDR into a wireless system, you're able to focus on developing your application on it, rather than working out how to make the device operate as a radio device in the first place. In fact, many manufacturers of SDRs use SoCs in their digital backend and develop their analog RFE and other PCBs and APIs around these.

Of course, SDRs do come with some disadvantages. For one, these devices tend to be more expensive than many RFSoC/SoC DFEs. Moreover, high-end SDR devices often use larger FPGAs and JESD transceivers between data converters, and thus consume considerable power (albeit, this can be optimized for various requirements). Another disadvantage of some SDRs is the size/form factors of such devices. While it's possible to make custom chassis/form factors for an SDR, they are generally much larger than small-form-factor RFSoCs/SoCs.

Suitable Applications for Each Transceiver Type

RFSoCs are currently being marketed to work with 4G/5G base-station equipment and other small-form-factor/low power consumption wireless systems. 5G base stations are often good applications of RFSoCs, particularly in remote radio head units (RRUs) in small-cell deployment due to the need for a very small form factor. Other applications include LiDAR for autonomous-vehicle technologies, as well as unmanned aerial vehicles (UAVs)/unmanned underwater vehicles (UUVs) that require low-power wireless communications.

3. This is Per Vices' Cyan and Host System/Storage & Playback solution. *Per Vices*

On the other hand, SDRs are useful for wide instantaneous-bandwidth (IBW) applications, such as spectrum monitoring and recording, which can be combined with storage and playback solutions *(Fig. 3)*. In addition, for a large swath of radar and satellite communications in higher frequencies, such as Ka- or Ku-bands, the higher tuning range of an SDR often is necessary.

The analog RFE also is much more suited for applications requiring better wideband dynamic range and/or spurious-free dynamic range (SFDR), such as in electronic-warfare (EW)/SIGINT applications. And when it comes to easier prototyping, SDRs likely are the better option, due to their ease of use with platforms such as GNU Radio and other DSP toolkits. They allow for much easier modification/redesign thanks to their simple interface, compared to having to develop a custom API or HDL code when using an RFSoC.

Conclusion

RFSoCs, DFEs, SDRs, transceivers—these are the many names for devices that do essentially the same thing: transmit and receive signals. There are numerous advantages and disadvantages of these devices. Furthermore, your application will determine how much time/money and resources you have to spend on development, as well as the SWaP requirements of such applications. As discussed, a high-performance SDR and an RFSoC are very different, and each has their pros and cons.

FRANZ DUGAND | Senior Director of Sales & Marketing, Wireless IoT Business Unit, CEVA

Dreamstime | Blackboard373 180755883

What's Powering Performance and Efficiency in the Latest Wi-Fi Standards?

As Wi-Fi 6E enters the market and Wi-Fi 7 prepares for ratification in 2024, examining the innovations introduced in recent generations underscores the reasons behind Wi-Fi's current performance and popularity.

Managed by the Wi-Fi Alliance since 1999, Wi-Fi (also known as WLAN or IEEE 802.11xx) has delivered the flexibility and convenience of wireless network connectivity at multi-megabit and, more recently, multi-gigabit data speeds.

Wi-Fi has proved to be a critical enabler for the services and freedoms many enjoy today, such as connecting to the internet easily and casually in any room at home, and in venues such as cafes and while traveling. Moreover, the ability to connect new devices without installing extra infrastructure is a key component for today's digital homes, populated by smart appliances and served by streaming entertainments, online gaming, and much more.

With the smart/connected home and wearables market segments now expected to drive major growth, market analyst ABI predicts Wi-Fi device shipments will exceed 5 billion units in 2026.

As always, enablement sparks rising demand, with more devices per household and per user, simultaneous streaming to multiple rooms, and the explosion of IoT applications (including building automation) all potentially using Wi-Fi to connect to the internet.

In response, successive generations of Wi-Fi standards have enabled higher

data rates and allowed a greater number of devices to connect to a given access point at any one time. The latest standards also add extra flexibility to support the needs of different types of connected devices.

Wi-Fi Evolution: MIMO and More

The *table* below summarizes the performance and features of the most recent generations of the Wi-Fi standard.

Wi-Fi has used both the 2.4- and 5-GHz frequency bands since its second generation (IEEE 802.11a). Subsequent generations have benefited from extra channels with increased bandwidth in each frequency band. However, some of the most powerful improvements included the adoption of multiple-input/multiple-output (MIMO) antenna channels, as well as frequency sharing.

Single-user MIMO (SU-MIMO) arrived with the 4th generation (IEEE 802.11n) to enhance both performance and connection range. While basic MIMO involves coordinating all router antennas to communicate with one client device, SU-MIMO in Wi-Fi 4 allows each router antenna to be allocated separately to individual client devices.

Wi-Fi 5 (IEEE 802.11ac) then introduced multi-user MIMO (MU-MIMO), among other enhancements including 256-QAM modulation. MU-MIMO makes it possible to manage connections with several clients in parallel, each on different spatial streams. However, in Wi-Fi 5, this is limited to downlink communications from router to client only. Also, the maximum number of parallel client connections is limited, typically from two to four, depending on the router antenna configuration.

Wi-Fi 6 applies the advantages of MU-MIMO to both uplink and downlink connections. In addition, Wi-Fi 6 increases the maximum MIMO configuration from 4x4 to 8x8, doubles the maximum channel bandwidth, adopts QAM-1024 modulation, and employs a OFDMA LTE-like modulation multiplexing scheme.

The combined effect of these advances increases the maximum data rate more than fivefold over Wi-Fi 5. Network efficiency is increased, too, particularly in dense areas where more devices can be connected to the same access points. This ensures a better user experience with higher throughput and lower latency. It's a major reason Wi-Fi 6 has achieved the fastest penetration rate ever for a new Wi-Fi generation.

MU-MIMO divides the MIMO operation of an access point (AP) between multiple users (or stations). Wi-Fi 6 allows for MIMO configurations of up to 8x8 antennas, which lets one AP handle up to eight 1x1 users simultaneously, one per spatial stream. The AP sends a single 8x8 MIMO packet over the air (downlink) containing data for each user on its respective allocated spatial stream. With MU-MIMO supported in the uplink as well, each user can reply simultaneously on its respective spatial stream.

Wi-Fi 6 also introduces multi-user OFDMA (MU-OFDMA). As a result, the total available bandwidth can be divided into resource units (RUs), making them available to multiple users so that more are able to connect to the AP. Up to 37 simultaneous users can share an 80-MHz channel, each using down to just 2 MHz of bandwidth. These narrowbands also enhance coexistence with other narrowband technologies in the same frequency range, such as Bluetooth, Thread, and Zigbee.

MU-MIMO and MU-OFDMA enable an AP to better schedule traffic among users, with proper granularity and better control on quality of service (QoS). Hundreds or even thousands of devices

	Wi-Fi 4 (IEEE 802.11n)	Wi-Fi 5 (IEEE 802.11ac)	Wi-Fi 6 (IEEE 802.11ax)	Wi-Fi 6E (IEEE 802.11ax)	Wi-Fi 7 (IEEE 802.11be)
Frequency bands operations	2.4GHz (2.402 – 2.494) 5GHz (5.030 – 5.990)	5GHz (5.030 – 5.990)	2.4GHz (2.402 – 2.494) 5GHz (5.030 – 5.990)	2.4GHz (2.402 – 2.494) 5GHz (5.030 – 5.990) 6GHz (5.925 - 7.125)	2.4GHz (2.402 – 2.494) 5GHz (5.030 – 5.990) 6GHz (5.925 - 7.125)
Maximum bandwidth per channel	2.4GHz: 40MHz 5GHz: 40MHz	2.4GHz: 40MHz 5GHz: 80MHz	2.4GHz: 40MHz 5GHz: 160MHz	2.4GHz: 40MHz 5GHz: 160MHz 6GHz: 160MHz	2.4GHz: 40MHz 5GHz: 160MHz 6GHz: 320MHz
Maximum number of non-overlapping channels	2.4GHz: 2	5GHz: 5 (80MHz)	2.4GHz: 2 (40MHz) 5GHz: 2 (160MHz), or 5 (80MHz)	2.4GHz: 2 (40MHz) 5GHz: 2 (160MHz), or 5 (80MHz) 6GHz: 7 (160MHz), or 14 (80MHz)	2.4GHz: 2 (40MHz) 5GHz: 2 (160MHz), or 5 (80MHz) 6GHz: 3 (320MHz), or 7 (160MHz), or 14 (80MHz)
Maximum MIMO configuration	4x4	4x4	8x8	8x8	16x16
Highest modulation	64 QAM	256 QAM	1024 QAM (1K QAM)	1024 QAM (1K QAM)	4096 QAM (4K QAM)
Maximum PHY datarate	600 Mbps	1.7 Gbps	9.6 Gbps	9.6 Gbps	46.1 Gbps
Multi user MIMO (MU-MIMO)	N/A	Downlink (Wave 2 only)	Downlink Uplink	Downlink Uplink	Downlink Uplink
Multi user OFDMA (bandwidth sharing)	N/A	N/A	Yes	Yes	Yes
Target Wake Time (TWT)	N/A	N/A	Yes	Yes	Yes (improved)
Multi Link Operation / Multi Resource Unit	N/A	N/A	N/A	N/A	Yes

Wi-Fi 4/5/6/6E features and performance. *CEVA*

may be connected to the AP with limited congestion. Moreover, the slower Wi-Fi 6 IoT devices can seamlessly coexist with Wi-Fi 6 high-demand devices without impacting their throughput and latency.

In addition, Wi-Fi 6 introduces target wake time (TWT), which enables devices connected to the AP to go into deep sleep and wake at a scheduled time to share data. This helps maximize energy savings in power-conscious devices and reduces conflicts.

Moving Forward with Wi-Fi 6E

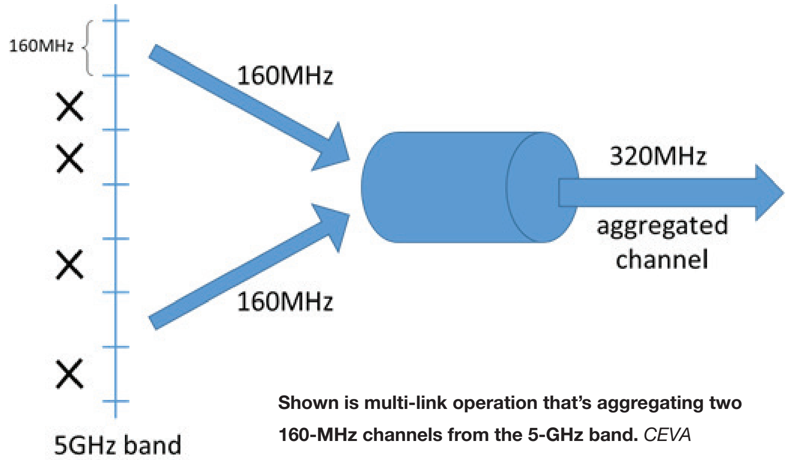
In addition to operating on the 2.4-GHz band, Wi-Fi standards from the second generation onward have used 5 GHz. As the 2.4-GHz band has become increasingly crowded with other technologies such as Bluetooth, Zigbee, and Thread, this higher band provides a means of avoiding congestion.

However, with continuously increasing demand for data bandwidth, pressure on the capacity of the 5-GHz channel has continued to grow. Video-streaming services are offering higher-resolution video, while the rollout of fiber-to-the-home delivers super-fast internet that then needs to be served out within the premises. The recent surge in working from home during the COVID-19 pandemic also increased the appetite for reliable, high-speed Wi-Fi.

Wi-Fi 6E addresses these pressures by adding the 6-GHz band (5.925 to 7.125 GHz) to further expand capacity. The extra 1.2 GHz of bandwidth provides seven extra channels of 160 MHz each. This contrasts with the 5-GHz band, which provides only two channels of such width. Alternatively, there are up to 14 channels of 80 MHz each, whereas only five of these were available on the 5-GHz band.

CEVA has developed Wi-Fi IP solutions that include MAC and modems for Wi-Fi 4/5/6/6E generations, supporting station/client (STA) and AP modes in SISO and MIMO configurations for bandwidths up to 160 MHz.

Wi-Fi 6E has already achieved widespread market adoption. The forthcoming generation, Wi-Fi 7, now promises additional, exciting advantages.



Shown is multi-link operation that's aggregating two 160-MHz channels from the 5-GHz band. *CEVA*

More of Everything with Wi-Fi 7

Wi-Fi 7 is almost 5X faster than Wi-Fi 6/6E. In addition, two important new innovations allow for flexible use of the resources to increase throughput and reduce latency. One is multi-link operation (MLO), which allows for aggregation of two channels from the same or different bands.

The 6-GHz bands provide three 320-MHz channels, although interference can prevent finding an entire channel to be available. With MLO, any combination of channels in the 5- and 6-GHz bands may be combined. This could be two disjointed 160-MHz channels from the seven available in the 6-GHz band, one channel on the 6-GHz band with another on the 5-GHz band, or two channels from the 5-GHz band *(see figure)*.

Another possibility is aggregation of 160- and 80-MHz channels on the 5- and 6-GHz bands. In addition, MLO can be used for load balancing, quickly and seamlessly switching between channels to minimize contentions and retries, which also reduces latency.

A second new concept introduced by Wi-Fi 7 is the multi-resource unit (MRU). It allows for aggregating two RUs to satisfy a large throughput requirement for a single user. Such a large bandwidth may not be free throughout the whole channel bandwidth, so a MRU aggregates RUs on the same channel.

The principle is similar to that behind MLO, and the aggregated units can be contiguous or disjointed. We expect Wi-Fi 7 solution providers to differ in terms of how, when, and which channels to aggregate.

With these two powerful innovations, Wi-Fi 7 performs particularly well where high throughput, low latency, and high link reliability are required. Examples include gaming, connectivity for AR/VR headsets, and video distribution. Moreover, Wi-Fi 7 will significantly improve experiences in dense environments such as airports and offices, where users are moving and frequently switch dynamically between emailing, browsing, chat, file transfers, and video conferencing.

Conclusion

Thanks to continuous evolution to meet user expectations and facilitate emerging use cases, Wi-Fi has remained enduringly popular and effective. With extra channels and frequency bands, SU- and MU-MIMO, and techniques for efficient resource sharing, the maximum data rate has increased from 600 Mb/s in the fourth generation to 9.6 Gb/s in Wi-Fi 6E.

Progress continues to accelerate and users accessing the internet through Wi-Fi 7 can look forward to significantly faster data speeds, greater flexibility and reliability, and lower latency. mw

SURESH PATEL | Sales Engineer, Mer-Mar Electronics

Effectively Overcoming RF PCB Antenna Design Issues

The article shares some practical tips for dealing with issues like noise sensitivity and tight impedance margins when designing antennas for an RF PCB.

Demand is on the rise for RF PCBs due to the current trends of wireless electronics, IoT sensors, smartphones, robotics, and more. An RF PCB operates at a very high frequency of 100 MHz and above.

Designing an RF circuit involves issues like noise sensitivity and tight impedance margins. When you add an RF antenna to the circuit, it brings additional complexities to the board's signal integrity. Choosing an experienced PCB manufacturer is one of the key factors in building high-quality RF PCBs.

An RF antenna transmits and receives electromagnetic radiation in a wireless circuit. The signal range depends on the antenna design, placement, enclosure, and ground plane size. To avoid signal corruption and interference from nearby digital components, a circuit designer must follow the PCB supplier's recommended RF PCB design guidelines. Correct antenna design and layout strategies can ensure analog signal integrity in mixed-signal PCBs.

RF Antenna: Basic Elements and Types

An effective antenna design—paired with a good PCB layout—can substantially increase the operating range of an RF PCB. An antenna converts the electrical energy fed from a signal generator into electromagnetic radiation. Primarily, an antenna is a conductor that transmits the signal into the free space. The length of the conductor should be a multiple of the signal wavelength to radiate the signal effectively.

The basic elements of an antenna include a conductive radiator that emits the signal, a reference plane to determine the antenna's orientation, an antenna feedline that provides the input signal to the antenna, and an impedance-matching network to ensure signal integrity and maximum power transfer at the set carrier frequency.

Different types of antennas are available:

- A PCB antenna is a trace etched on the circuit board in any specific shape depending on the design requirement and space constraints. It's a 2D structure in the same PCB plane and can be easily manufactured.
- A wire antenna is a 3D extension over the PCB and protrudes into the space. It provides the best performance and higher RF range due to its external exposure.
- Chip antennas are suitable for compact PCB products, but they're expensive. These antennas are sensitive to RF GND size and may require an extra matching network for antenna tuning.

It's recommended to select the antenna type based on the RF range to be covered, cost allocated, the board size, and required radiation intensity in a particular direction.

Design, Placement, and Layout issues

After choosing the antenna design type, one must understand the effects of placement, enclosure, and ground plane size on the RF antenna performance.

Antennas are sensitive to the PCB RF ground plane size and the plastic casings. The resonant frequency reduces with an increase in the effective capacitance due to a larger RF ground size or a bigger plastic casing.

To achieve better RF performance, the return path should be uniform. If the ground plane is interrupted, the return signal may switch to the smallest path available and affect the impedance matching between the antenna and the radio.

Antenna placement must be aligned with the RF product's final orientation to reach maximum radiation in the chosen direction. The matching network should be carefully designed as multiple parameters can affect the antenna's impedance. While radiating the signal, strong coupling may occur between feeding lines and radiating elements, which can impact the antenna performance.

In a high-power application like space systems, the feed circuit to the antenna should be immune to the corona discharge effect, which can damage the antenna itself. Prior simulation and testing of the antenna with the designed feed circuit is recommended to avoid such issues.

Guidelines for Designing RF PCB Antennas

The guidelines for RF PCB antenna design assist in ensuring there's efficient radiation from the antenna. They also suggest placement methods for maximum isolation between the analog and digital sections as well as offer electromagnetic-compatibility tips in resisting unnecessary signal reception from neighboring devices. Here are some guidelines for designing better RF PCB antennas:

- The antenna should be placed in one corner of the PCB with enough clearance from the remaining part of the circuitry.
- Maintain strict antenna keep-out areas in every layer of the PCB stackup. No components, planes, or traces should be placed in the RF antenna keep-out area.
- The ground pattern varies based on the type of antenna used in the RF PCB design. It's recommended to follow the corresponding antenna manufacturer's reference design to include appropriate ground patterns.
- Antennas should be placed away from any plastic casing on the PCB to avoid variation in its resonant frequency.
- No metallic enclosures are allowed to cover the RF product completely. The antennas are always kept out of such enclosures.
- The antenna should be placed in line with the overall product orientation to facilitate maximum radiation.
- No cable can cross the antenna trace on the PCB positioned on the same side of the antenna.
- Include ground clearance from the antenna with a minimum width as per the manufacturer's reference document.
- Always follow the manufacturer's datasheet while designing the antenna matching network, considering the right antenna trace length, final plastic enclosure placement, and other recommendations.
- Provisions for a matching network are suggested to be included in the RF PCB design using 0E (or zero-ohm) resistors, in case of unknown antenna impedance (due to substrate differences, ground variations, or proximity of plastic casings).
- To provide isolation to the RF-sensitive elements on the board, it's advised to use shielding structures like ground pours, via fences, waveguide routing techniques, etc. Also, the latest EDA tools support simulations to understand the radiation effects on the PCB, which can be used while designing the RF circuits.

Conclusion

To effectively overcome RF PCB antenna design issues, it's necessary to adhere to the above guidelines and work with an experienced RF PCB manufacturer.

Manufacturers can offer layout suggestions like using inner PCB layers as PWR-GND planes to provide shielding effects, packing critical signals to avoid interference from noise signals, and many others. If the manufacturer has enough experience in RF PCB manufacturing or PCB prototyping, they can come up with great suggestions that might help you.

Recently, the software tools used for PCB designs also help ensure the isolation and signal integrity of the RF design. mw

Design Feature

BOB O'DONNELL | President, TECHnalysis Research

5G Fuels Shift to O-RAN Architectures—and Its Security Challenges

As the telecom industry evolves from a proprietary hardware-driven world to 5G O-RAN architectures, addressing all possible security concerns has become the top priority for network equipment vendors and service providers.

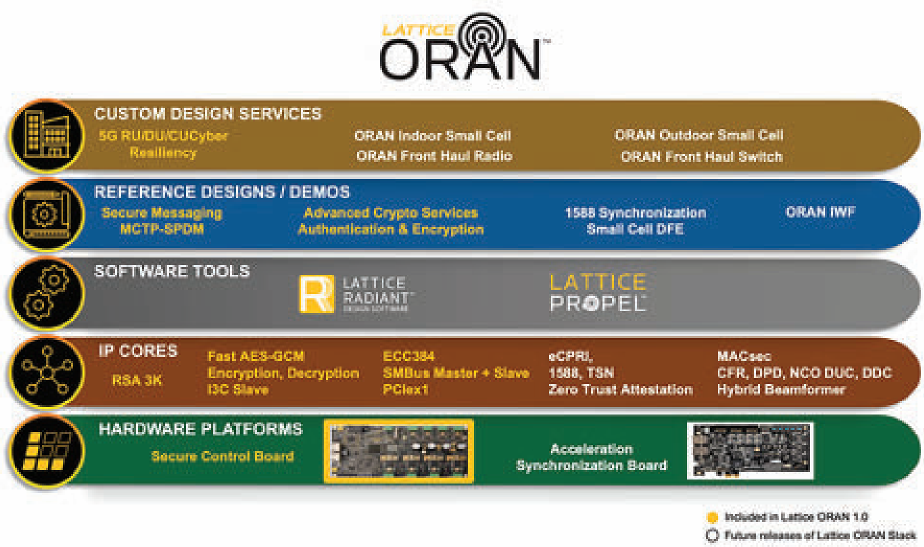
Network evolution and the adoption of 5G is forcing telecommunication vendors to adapt at a rapid pace as more and more devices are expected to be connected to the network at any given time. In fact, 3.6 billion 5G connections are expected by 2025, and that number is expected to grow to 4.4 billion by 2027. In response, the telecom industry is beginning its transition to O-RAN (Open Radio Access Network) types of architectures to increase network flexibility and efficiency.

However, this shift doesn't come without challenges. While moving to an O-RAN architecture opens up all sorts of advanced network possibilities, it also dramatically increases the potential attack surface for a network. The attack surface is the totality of all vulnerabilities in connected hardware and software that are accessible to unauthorized users.

That risk of attack increases especially because O-RAN architectures enable system designers to mix and match hardware and software from different vendors. As a result, network architects and hardware designers must consider every possible connection and ensure that each is safe and secure—a multi-step process that's easier said than done.

The Need for Platform Firmware Resiliency

As the attack surface of networks increases, it's no longer a matter of whether a network will be attacked, but rather when it will happen. Therefore, hardware designers must move for-



Lattice Semiconductor's O-RAN solution stack combines reference platforms and designs, demos, IP building blocks, FPGA design tools, boards, and custom design services. System designers can utilize the solution stack to enable robust control data security, flexible fronthaul synchronization, and low-power hardware acceleration for secure, adaptable, Open Radio Access Network (O-RAN) deployment. *Lattice Semiconductor*

ward with platform firmware resiliency (PFR) in mind.

PFR is a cyber resiliency system that compute systems can count on to actively protect and keep themselves running and functional to a very high degree while under attack. The first step to achieving PFR is using a device that serves as a hardware root of trust (HRoT) to confirm a device's firmware hasn't been tampered with throughout its lifetime.

Because security threats begin at the hardware level, no matter how many connections there are across a network, designing with an HRoT device is critical to achieve PFR. Low-power FPGAs are particularly well-suited to serve as HRoTs because of their flexibility and small form factors. FPGAs with built-in cryptographic capabilities can encrypt and decrypt incoming and outgoing firmware data to ensure secure firmware updates.

Because security threats begin at the hardware level, no matter how many connections there are across a network, designing with an HRoT device is critical to achieve PFR.

Leveraging a Zero-Trust Security Model

Protecting the integrity of firmware is only the start to maintaining the security of hardware elements in O-RAN architectures. With O-RAN systems comprising different hardware from various vendors, any two endpoints that carry data pertaining to network functions or user data must be protected—a process also known as "securing the wire." When leveraging a zero-trust security model like securing the wire, every system component must confirm its authenticity to the host system using encrypted messages.

This is where FPGAs with built-in RISC-powered CPU cores come into play *(see figure)*. With the inherent flexibility of FPGAs, CPU cores can be programmed to implement cryptographic and secure messaging protocols. Because FPGAs are reprogrammable, they're ideal for accelerated scalability and can help hardware designers keep pace with 5G innovation without sacrificing security and designs.

Securing Data-Synchronization Connections

While securing the hardware elements in an O-RAN architecture is critical, so is securing the timing controls of data sent across a network's hardware elements. Older closed RANs typically contain a shared clock signal that coordinates the bonding of radio signals coming in at different frequencies into a single chunk of digital data.

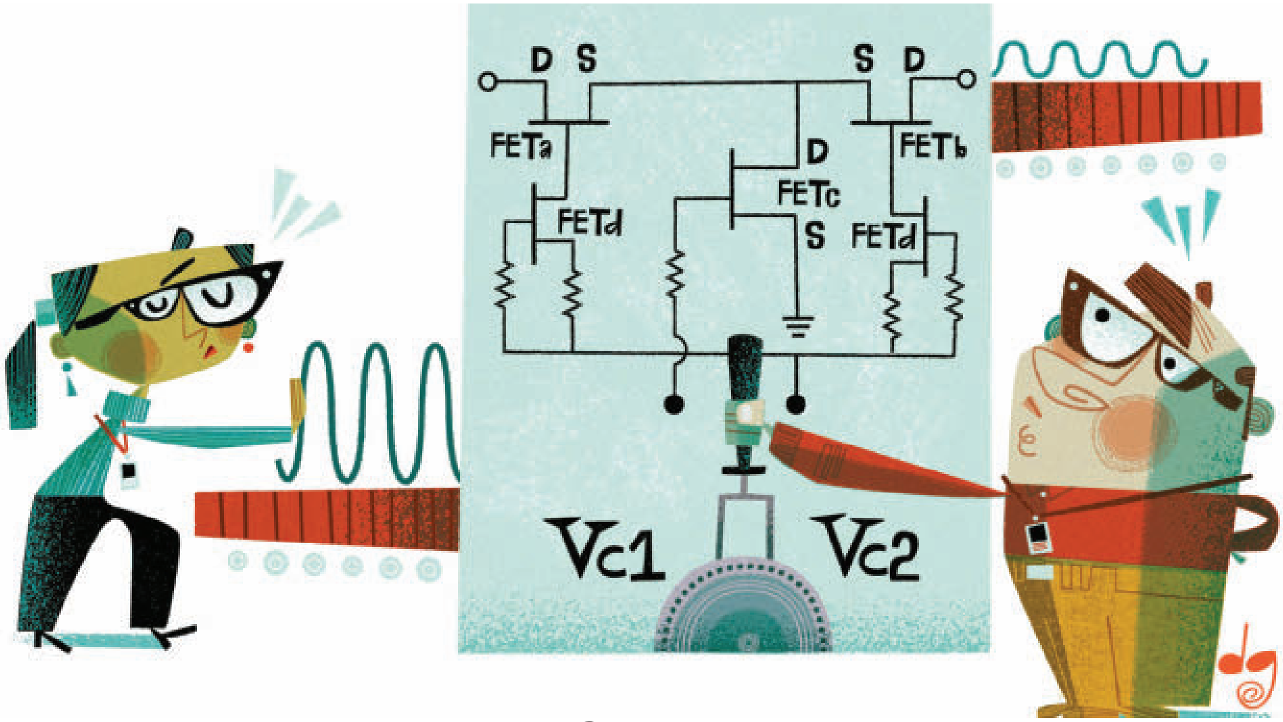
In an O-RAN system, such bonding still needs to happen. However, with radio units and distributed units now disaggregated, the shared clock signal is no longer an option.

Using the IEEE 1588 precision time protocol standard, O-RAN systems must time-stamp data packets so that they're synchronized across components. FPGAs have historically been used as a reliable timing resource in various applications, and this remains true in O-RAN architectures. Thanks to the concurrent and consistent way FPGAs operate, they're a perfect fit to meet the synchronization demands for functional-split options where radio units and distributed units are separated.

Addressing 5G O-RAN Architecture Security Challenges with FPGAs

As 5G continues to fuel the shift to O-RAN architectures, FPGAs, though small and easily overlooked, offer the flexibility, reliability, and low power consumption required to meet evolving security challenges found across networks. While serving as HRoT devices, powering zero-trust security models, and keeping data-synchronization timing controls tight and secure, FPGAs are playing a critical role in accelerating 5G O-RAN deployments. mw

ANTON PATYUCHENKO | Field Applications Engineer



RF Demystified: What is an RF Attenuator?

This article covers the basics of attenuator ICs, including the various types, design configurations, and key specifications you'll need to know when specifying them.

The attenuator is a control component, the main function of which is to reduce the strength of the signal passing through it. This type of component is generally used to balance signal levels in the signal chain, to extend the dynamic range of a system; provide impedance matching; and implement various calibration techniques in the end application design.

Types of Attenuators

From the key functional perspective, attenuators can be classified as fixed attenuators with an unchanging level of attenuation and variable attenuators with an adjustable level of attenuation. Depending on the form of attenuation control supported by variable attenuators, they can in turn be further classified as voltage variable attenuators (VVAs), featuring analog control, and digital step attenuators (DSAs) that are controlled digitally.

VVAs provide continuous adjustment of attenuation levels that can be set to any value within the given range. Analog variable attenuators are usually employed for automatic-gain-control circuits, calibration corrections, and other processing functions where smooth and precise control of a signal is required.

DSAs feature a set of discrete attenuation levels allowing for signal-strength adjustments with a predetermined attenuation step size. Digitally controlled RFIC attenuators offer a control interface compatible with microcontrollers and provide a good solution to maintain functional integrity in complex designs.

Design Configurations

Attenuator ICs can be realized in GaAs, GaN, SiC, or CMOS technologies using resistors, PIN diodes, FETs, HEMTs, and CMOS transistors. *Figure 1* shows three basic topologies that underlie various types of attenuator design configurations: T-type, π-type, and bridged-T networks.

Fixed-value attenuators use these core topologies realized with resistors in thin-

film and thick-film hybrid technologies to provide fixed levels of attenuation.

VVAs typically use a T-type or π-type configuration with a diode or transistor elements operated in a nonlinear resistance region. The resistance characteristics of the base elements are exploited to adjust the required level of attenuation by varying the control voltage.

DSAs usually employ multiple cascaded units representing individual bits that can be switched in or out to achieve the required level of attenuation. A few configuration examples used for DSA designs are shown in *Figure 2*.

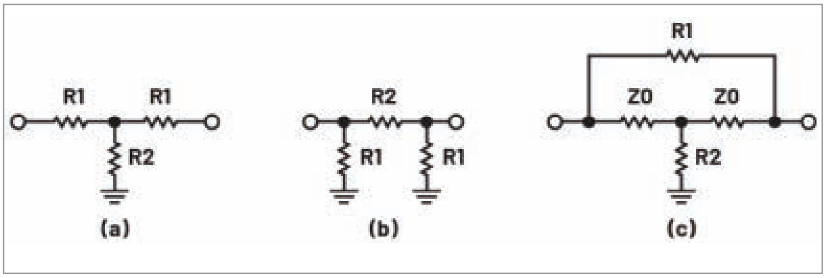
Configurations include integrated SPDT switches that toggle input and output ports with the attenuating pad and a through line, switched-scaled device designs with transistors or diodes used as switchable resistances, switched-resistor configuration where the resistors can be switched in or out of the circuit, and device-embedded type design with a transistor or a diode as an integral part of the design.

Attenuator topologies can be arranged into a reflection- or balanced-type design *(Fig. 3)*. Reflection-type devices use equal attenuators connected to the output of a 3-dB quadrature coupler and typically offer a large dynamic range. Balanced configurations combine a pair of identical attenuators using two 3-dB quadrature couplers and provide good VSWR and power-handling capability.

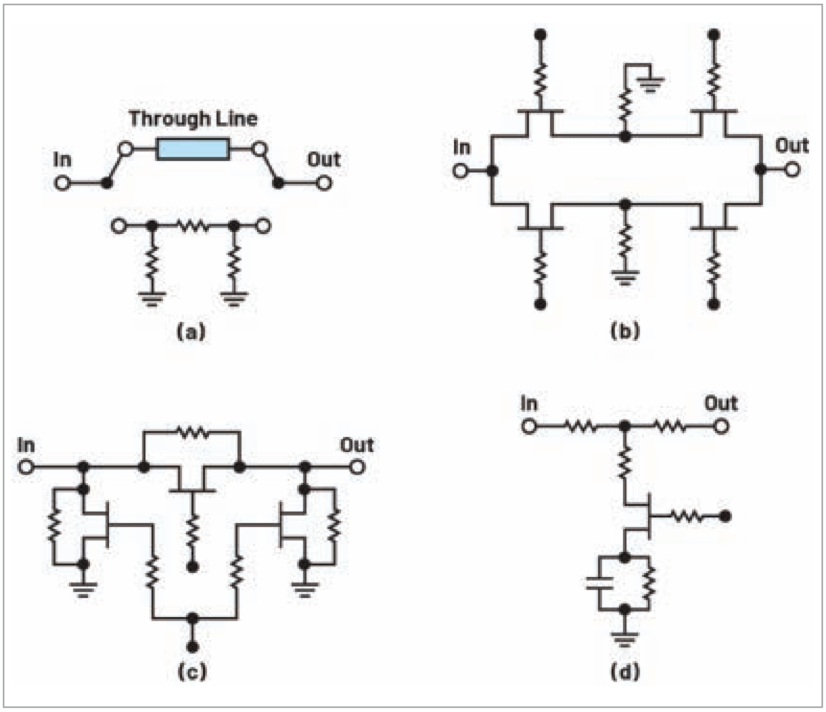
In addition to the main design configurations described in this article, other types of circuits are utilized for realization of IC attenuator components; however, their consideration is beyond the scope of this short article.[1,2]

Key Specifications

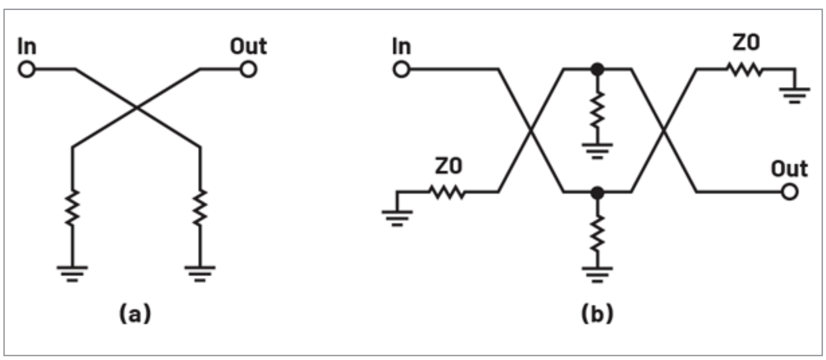
To select the right type of an attenuator for the end application, an engineer must have a good understanding of its key specifications. Apart from the attenuation capabilities and some fundamental parameters such as insertion and return loss, other key characteristics are used to describe attenuator components:



1. Shown here are the three basic topologies that underlie various types of attenuator design configurations: T-type (a), π-type (b), and bridged-T networks (c). *Analog Devices*



2. These are some DSA design configuration examples: π-type configuration with integrated switches (a), switched-scaled FET configuration (b), switched-resistor configuration (c), and FET-embedded configuration (d). *Analog Devices*



3. Attenuator topologies can be arranged into a reflection- or balanced-type design, shown schematically in (a) and (b), respectively. *Analog Devices*

- *Frequency range (Hz):* The frequencies over which the IC maintains its specified characteristics.
- *Attenuation (dB):* The amount of suppression above and beyond the insertion loss.
- *Frequency response:* Variation of the attenuation level (dB) across the frequency range (Hz).
- *Attenuation range (dB):* The total value of attenuation offered by the component.
- *Input linearity (dBm):* It's usually expressed in terms of the third-order intercept point (IP3), defining a hypothetical point for the input power level at which the power of the corresponding spurious components would reach the same level of the fundamental component.
- *Power handling (dBm):* It's typically described in terms of the input 1-dB compression point defining the input power level at which the insertion loss of the attenuator decreases by 1 dB; the power-handling characteristic is often specified for the average and peak input power levels for the steady-state and hot-switching modes.
- *Relative phase (degrees):* A shift in phase introduced to a signal by the attenuator component.

In addition to these common parameters, variable attenuators also are described by their switching characteristics. They're typically expressed in nanoseconds in terms of rise and fall time, on and off time, and the amplitude and phase settling time of the RF output signal.

There are also specific characteristics inherent to each type of variable attenuator. For VVAs, they're related to their analog control operation:

- *Voltage control range (V):* The voltages required to adjust the attenuation level within the attenuation range
- *Control characteristics:* These are usually expressed in terms of the attenuation slope (dB/V) and the performance curves showing the level of attenuation as a function of control voltage

For DSAs, their inherent characteristics, in turn, include:

- *Attenuation accuracy (also known as the state error, dB):* The limit of variation in the attenuation level relative to the nominal value
- *Attenuation step size (dB):* The delta between any two successive attenuation states.
- *Step error (dB):* The limit of variation in the attenuation step size relative to the nominal value.
- *Overshoot and undershoot (dB):* The level of signal transients (glitches) during state transitions.

A good attenuator component is generally required to deliver flat attenuation performance and good VSWR across the operational frequency range, to offer sufficient accuracy and power-handling capability, and to ensure smooth glitch-free operation with little signal distortion during state transitions or to provide linear control characteristic.

Conclusion

The broad diversity of IC attenuator components certainly isn't limited to only those discussed in this article. We can recognize other types of ICs, including frequency-dependent and phase-compensated attenuators, temperature variable attenuators, programmable VVAs with an integrated digital-to-analog converter (DAC), and others.

However, in this article, we considered the most common categories of IC attenuators and discussed their main topologies and key specifications, which can help an RF designer to choose the right component for an end application. mw

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2. Ian Robertson and Stepan Lucyszyn. *RFIC and MMIC Design and Technology,* The Institution of Engineering and Technology, November 2001.

50-GHz Digital Step Attenuator Ranges from 0 to 31.5 dB in 0.5-dB Steps

The wideband DSA is immune to latchup, offers low insertion loss, and is broadly applicable in test applications for 5G, satcom, and electronic-warfare test sets.

MINI-CIRCUITS' ZX76-50G-30-V+ DIGITAL step attenuator (DSA) is a 50-Ω device that delivers adjustable attenuation from 0 to 31.5 dB in 0.5-dB steps. With operation specified from 100 MHz to 50 GHz, it can function at frequencies up to 55 GHz.

The DSA is controlled through a 6-bit parallel interface with a single positive supply voltage of +2.3 to +5.5 V (+3.3 V nominal). The six control bits select the desired attenuation state. Thanks to its VSWR of just 1.5:1 (typical), the unit is easy to interface with adjacent components and provides low-amplitude ripple.

A novel architecture reduces RF output-power spikes during attenuation to 0.3 dB (typical), which reduces system noise and eliminates risk of a transient spike that could damage sensitive components. In addition, the use of a single positive supply simplifies power-supply design. An internal negative-voltage generator supplies the desired negative voltage.

The device has multiple applications in communications, satcom, and defense test setups. Use cases include 5G; X-band, S-band, C-band, Ku-band, and K-band radars; and electronic-warfare test sets. ■

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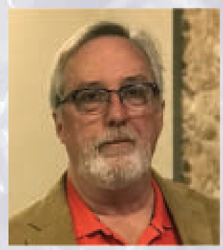

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Bluetooth: The Great Configurator

Matter is a unifying connection environment for IoT, but adding something to the mix often includes Bluetooth.

To start with, Matter is supported by the Connectivity Standards Alliance. Matter is probably the worst name they could come up with because you can't find anything about it using the search engines, but nonetheless it's becoming the Rosetta Stone of IoT.

Matter is designed to unify disparate networks that are employed in IoT applications like smart-home and smart-office environments and the growing industrial IoT (IIoT) environment. There are a multitude of protocols and communication links from Wi-Fi to 5G to 802.15.4. IPv6 tends to be a common low-level protocol, but it takes more than a simple connection to make devices play together. Trying to get a light switch on one network to turn on a light connected to another network isn't as easy as it sounds. Matter is designed to address that situation.

An in-depth look at Matter will have to wait, though, as this article looks at how devices are being added to networks.

1. The CY8CKIT0 PSoC Pioneer Kit includes the CYW43012 Wi-Fi + Bluetooth Combo Chip as well as the PSoC 62 Line host microcontroller with a 150-MHz Cortex-M4 and a 100-MHz Cortex-M0. *Infineon Technologies*

Once connected to a network, the management through platforms like Matter come into play. However, getting them there is often accomplished using Bluetooth and a smartphone app. This affects how devices are designed because they need to support Bluetooth and often another wireless protocol like Wi-Fi, Zigbee, or Z-Wave.

Security and Connecting Via Bluetooth

Luckily, most networks these days are designed to run, and even are initially configured to work with, encryption for connectivity and often for data transport. Way back when, a Wi-Fi router/access point would start up with no encryption enabled. Now there's usually a device-specific username and password on the device, and accessing the wireless network requires an additional password.

Connecting a device like a smart TV is something that can often be done in a standalone mode, because it's obviously equipped with a display. A remote-control device can be used along with the user interface to connect to a Wi-Fi network that has password protection.

This isn't the case for many IoT devices, which often lack everything short of a way to provide power. Sometimes they even include a status LED.

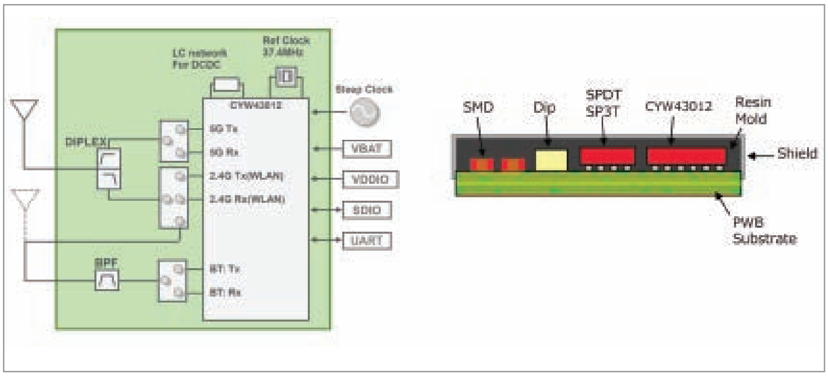
So how does one connect these devices that are devoid of a built-in user interface? Answer: Use a smartphone app connected to the device via Bluetooth.

Typically, a security handshake occurs.

The smartphone often uses its camera to scan a QR code that can provide all sorts of information from the smartphone app to download to a secure password associated with the device being configured.

Bluetooth can be used as the device's main connectivity mode, but it lacks many of the features of other alternatives, from increased range to higher throughput to even low power consumption—and Bluetooth isn't a power hog.

As a result, the device typically must employ two wireless interfaces: Bluetooth and something else.



2. Murata's 1LV Module is a multi-die system that provides Wi-Fi and Bluetooth support based around the CYW43012. *Infineon Technologies*

Dual-Mode Wireless SoCs

In the case of Infineon's AIROC CYW30739, the two wireless interfaces are Bluetooth Low Energy (BLE) and 802.15.4. The latter supports protocols like Thread that works with Matter as well as other open and proprietary wireless mesh networks.

Another is Infineon's CYW43012 Wi-Fi + Bluetooth Combo Chip, which is found in the CY8CKIT0 PSoC Pioneer Kit *(Fig. 1)*. The kit includes a PSoC 62 Line host microcontroller with a 150-MHz Cortex-M4 and a 100-MHz Cortex-M0. Also on-board is an Excelon very-low-power F-RAM.

The wireless support is provided by Murata's 1LV Module with Wi-Fi and Bluetooth capability *(Fig. 2)*. This multi-die module has its own shield and includes the CYW43012 chip.

The systems are supported by Infineon's ModusToolbox. They also support the open-source Mbed OS developed by Arm. Of course, Matter support is part of the mix, too.

Infineon isn't alone in delivering dual-mode wireless SoCs and many protocols still lack this combination. Likewise, there are other ways to tie in a new device to a wireless network, such as using the connection to the network to let it know what new device is being added. mw

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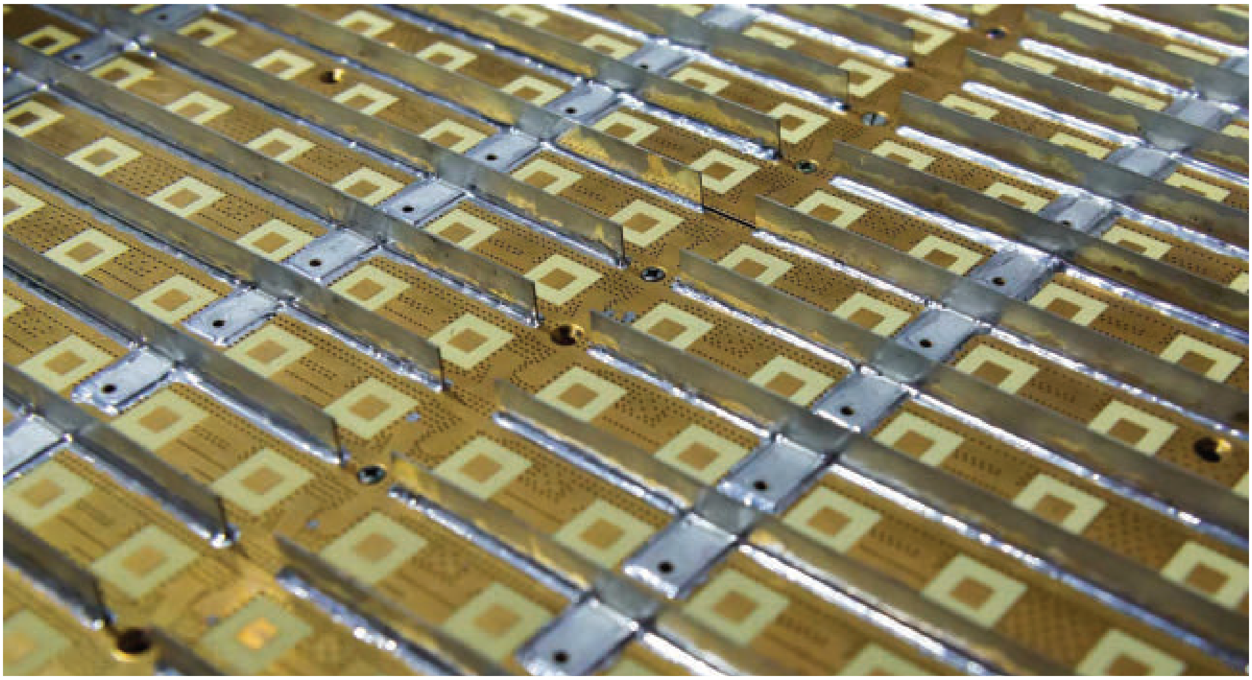

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When to Combine True Time Delays and Phase Shifters in a Hybrid Beamforming Approach

While electronic beamforming can be accomplished using either phase shifters or true time delays, both have pros and cons. Consider combining them in a hybrid beamforming technique that offers better SWaP-C and a comparatively less complex system design.

ELECTRONICALLY SCANNED ARRAYS (ESAs) utilize phase shifters (PSs), true time delays (TTDs), or a mix of both to point the summed beam toward the desired direction within an array's steering angle limits. Adjustable attenuators used for tapering also can be considered as beamforming elements.

This article discusses where and how a tiered approach between TTDs and PSs in the same ESA can be helpful to mitigate some phased-array design challenges.

Leverage Fundamental Formulas to Explore Possible Scenarios

Instantaneous bandwidth (IBW) can be defined as the frequency band where no tuning is required to stay within the target performance criterion set by the system requirements.

TTDs exhibit constant phase slope over frequency; therefore, ESAs implemented with TTDs instead of PSs don't have beam squint effect. As a result, TTD-based ESAs are more convenient for high-IBW applications.

PSs exhibit constant phase over their operating frequency range. Hence, a particular phase-shifter setting throughout the system results in different beamsteering

angles for different frequencies. Consequently, PS-based arrays tend to have narrower IBW compared to TTD-based arrays.

This phenomenon is called beam squint and it can be calculated using Equation 1, where Δθ is peak squint angle, θ_0 is maximum beam angle, f_0 is carrier frequency, and f is instantaneous signal frequency:

$$\Delta\theta = sin^{-1}\left(\frac{f_0}{f} \times sin\theta_0\right) - \theta_0 \qquad (1)$$

Using Equation 1, we can calculate that Δθ at worst case, which is at the low frequency edge (carrier at 3 GHz and instantaneous signal at 2.9 GHz), is around 1.15 degrees for a ±30-deg. beamsteering-angle system for a signal at 3 GHz with an IBW of 100 MHz. Changing beamsteering angle to ±60 deg. and IBW to 200 MHz results in a worst-case beam squint of around 8.11 degrees.

It's evident that TTDs can be a better choice even in radar applications. Arguably, phase-shifter dominance in ESAs is explained by the fact that PSs have had wider market availability due to their design simplicity and cost advantage over TTDs.

If we had a TTD that meets the system requirements, how might it be reasonable to use PSs in the same signal chain? To investigate, we'll examine a 32 × 32 square ESA with d = λ/2 lattice spacing between antenna elements desired to operate between 8 and 12 GHz with a ±60-deg. scanning angle. EIRP criteria is assumed to be met for all scenarios.

In this example, the system beamwidth in both azimuth and elevation would be ≈3.17 deg. at boresight (θ = 0 degrees) and ≈6.35 deg. at the maximum scan angle (θ = 60 deg.) by the half-power beamwidth approximation formula for a uniform linear array given in Equation 2:

$$\theta_B = \frac{50.764\,\lambda}{Nd\,cos\,\theta} \qquad (2)$$

where N is the number of elements on one axis and θB is the beamwidth in degrees on the same axis.

The maximum beam-angle resolution (θ_{RES_MAX}) of this array would be approximately ≈0.056 deg. in one dimension when using 6-bit, 5.6-deg.-LSB PSs behind every antenna element:

$$\theta_{RES\_MAX} = sin^{-1}\left(\frac{\Phi_{LSB}}{\pi} \times \frac{2}{N}\right) \qquad (3)$$

Approximately 1.3-ps LSB TTDs would be required to replace 5.6-deg.-LSB PSs to have a 0.056-deg. beam angular resolution at 12 GHz (from Equation 4, which is used for conversion between time and phase shift):

$$T = \frac{\Delta\Phi}{2\pi f} \qquad (4)$$

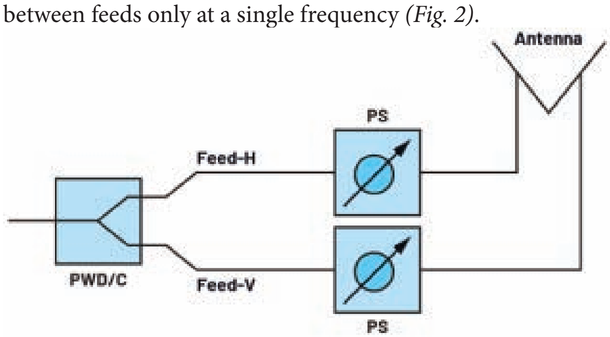
The beamwidth value is considerably greater than the beam angular resolution even at very small scan angle. Placing PSs on the same line with TTDs to compensate for beam angular resolution would introduce additional beam squint and degrade beam angular resolution.

In practice, the reason to have finer TTD resolution is to maintain lower quantization sidelobe levels (QSLLs) rather than having finer beam angular resolution. As the frequency goes higher, designing a TTD with the required time resolution to meet the target QSLL criteria gets relatively more difficult than designing a PS with a required phase resolution. Therefore, PSs can work with TTDs to achieve the target QSLL while still having an acceptable level of beam squint.

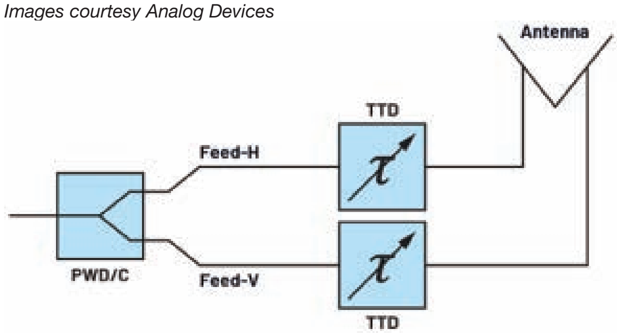
Cross-Polarization Systems

Another reason to implement PSs and TTDs in the same ESA could be to mitigate beam squint while designing a system with cross-polarization capability. Cross polarization is generated by setting a 90-deg. phase shift in between the V and H feeds of antenna elements. Ensuring as close to a 90-deg. difference as possible between feeds over the desired cross-polarization bandwidth is essential to having good cross-polarization isolation for healthy operation.

Because they offer a constant phase over frequency, PS-based ESAs have a wideband cross-polarization capability *(Fig. 1)*. TTD-based ESAs, on the other hand, can have 90 degrees between feeds only at a single frequency *(Fig. 2)*.

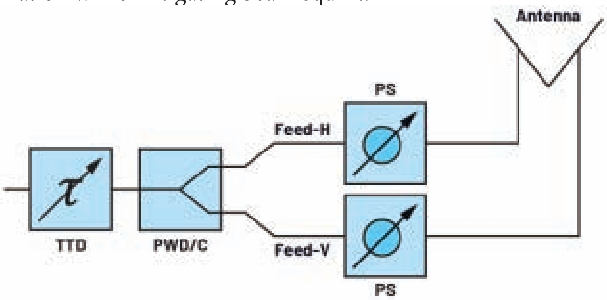


1. As seen here, phase shifters behind the V and H feeds of antenna elements provides non-squint-free, wideband cross polarization.
Images courtesy Analog Devices



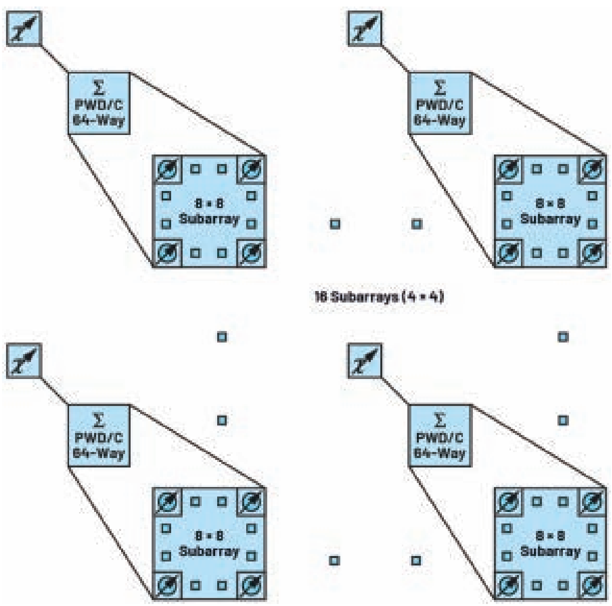
2. To obtain squint-free, narrowband cross polarization, use true time delays behind the V and H feeds of antenna elements.

One may use the architecture in *Figure 3* to apply cross polarization while mitigating beam squint.



3. Placing a true time delay on common legs and phase shifters behind the V and H feeds of antenna elements both optimizes beam squint and offers wideband cross-polarization capability.

TTD coverage is set by the maximum delay Δt_{MAX} between the most distant elements of the whole array at the lowest frequency of operation. Using Equation 5, this is around 2.45 ns for the example array in *Figure 4*.



4. Shown here is a 1024-element (32 × 32) array partitioned into 16 subarrays consisting of 8 × 8 elements.

There are a couple of things to consider when using TTDs behind every antenna element instead of PSs if cross polarization isn't required. This coverage means a significantly high loss and could be challenging to implement given the antenna spacing. Having the resolution of a 6-bit PS with the given coverage would bring some design challenges, along with many delay stages to be placed into TTDs.

If the resolution is preserved and the coverage is reduced to mitigate these drawbacks, then one would have to wrap back through zero when exceeding the coverage (by calculating the phase equivalent using Equation 4). However, ironically, the beam-squint feature would be lost.

This quick analysis shows that PSs at every antenna element followed by TTDs at the common legs of the subarrays can be useful even when cross polarization isn't required. The TTDs in *Figure 4* would again need to have the same coverage. This time, though, the resolution requirement is relaxed compared to the scenario of a TTD at every antenna element, because they're now used to align relatively larger time delays between subarrays.

Breaking down a phased array into subarray partitions lowers the cost and complexity of a system at the expense of a higher scan loss and lower beamsteering resolution. By having wider beamwidth, subarrays are more tolerant to beam-squint effects as they have wider beamwidth. It's apparent that beam squint and beamwidth targets are important metrics with consideration to the subarray size.

Conclusion

True time delays behind every antenna element are required for broadband, squint-free operation; and phase shifters behind every V and H feed of each antenna element are required for broadband cross-polarization operation.

If you don't need cross polarization but are seeking fully squint-free operation, go with a TTD-based design. As the frequency increases, adding PSs could help meet the QSLL target with the tradeoff of compromised squint-free operation.

If cross polarization is required, then each polarization feed of the antenna should be followed by separate but identical PSs with a tight 90-deg. difference above the operational bandwidth. Adding TTDs on the common leg of PSs could help to mitigate the beam squint.

Whether cross polarization is required or not, a subarray architecture with PSs behind antenna elements followed by TTDs at the common legs of subarrays can be a cost-effective solution. Note that TTD functionality may be implemented in the digital domain—an all-digital design can eliminate both TTDs and PSs at the expense of a higher system cost.

Before diving into the countless challenges of ESA design, understanding the differences in using either TTDs or PSs versus using them in tandem is an essential part of planning a system-level beamforming architecture that meets the system requirements with better SWaP-C. mw

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Coaxial Mixer Spans 2- to 65-GHz RF/LO Range

Mini-Circuits' model ZMDB-653H-E+ coaxial frequency mixer features a RF and LO frequency range of 20 to 65 GHz and IF range of dc to 20 GHz. Well-suited for frequency downconversion/upconversion in defense radar, communications, and test systems, the Level 15 (+15 dBm LO power) mixer measures 0.56 × 0.56 × 0.34 in. (14.22 × 14.22 × 8.64 mm) with female 1.85-mm connectors. Typical LO-RF isolation is 45 dB with typical conversion loss of 11 dB from 20 to 65 GHz.

MINI-CIRCUITS, www.minicircuits.com/WebStore/dashboard.html?model=ZMDB-653H-E%2B

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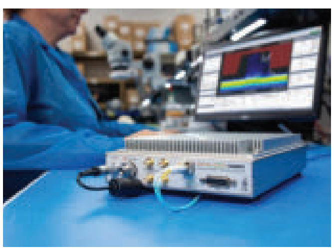
TDK's B32354S* series of metallized EPCOS polypropylene capacitors for filter applications feature a 4-pin design and a pitch of 52.5 mm. With a Vrms of 275 V ac or 350 V ac and a capacitance range from 10 to 40 µF, the maximum operating temperature is 85°C. With a high resistance to harsh operating conditions and certified to IEC 61071, the compact caps offer a life of at least 100,000 hours and a failure rate of less than 5 FIT. With its integrated safety function, the series meets the highest safety level (10,000 AFC) and is UL 810 approved. The capacitors carry the CE mark, and the housing and potting material comply with UL 94 V-0.

TDK ELECTRONICS, www.tdk-electronics.tdk.com/en/529468/products/product-catalog/film-capacitors/ac-film-capacitors

Spectrum Analyzer Remotely Performs Accurate RF Data Analysis



Signal Hound's SM435C 43.5-GHz, high-performance spectrum analyzer and monitoring receiver includes a 10-Gigabit Ethernet SFP+ port, enabling the analyzer to communicate with a PC over long distances using a fiber-optic cable. Designed for remotely located accurate RF data analysis, the SM435C also includes a signed calibration certificate and a printed packet of calibration data.The Option-80 variant of the device provides downconverter functionality, allowing engineers working with 5G to utilize 800 MHz of continuous real-time data for in-depth analysis. The SM435C Option-80 also serves applications requiring extremely clean phase noise.

SIGNAL HOUND, www.signalhound.com/products/sm435c-43-5-ghz-real-time-spectrum-analyzer-with-10gbe/

Microcontroller Add-on Board Accelerates Embedded Development

MikroElektronika (MIKROE) launched its latest SiBRAIN add-on board for the GD32VF103VBT6, enabling embedded designers to immediately begin prototyping with the GigaDevice RISC-V microcontroller. SiBRAIN is equipped with two 168-pin mezzanine connectors, allowing it to support even MCUs with extremely high pin count. GigaDevice's GD32VF103 is a 32-bit general-purpose microcontroller that incorporates the RISC-V 32-bit processor core operating at 108-MHz frequency with flash accesses that have zero wait states to obtain maximum efficiency. It provides up to 128-kB on-chip flash memory and 32-kB SRAM memory. An extensive range of enhanced I/Os and peripherals are connected to two APB buses. The device offers up to two 12-bit ADCs, two 12-bit DACs, four general 16-bit timers, two basic timers plus a PWM advanced timer, as well as standard and advanced communication interfaces: up to three SPIs, two I2Cs, three USARTs, two UARTs, two I2Ss, two CANs, and USBFS. The RISC-V processor core also is tightly coupled with an Enhancement Core-Local Interrupt Controller (ECLIC), SysTick timer, and advanced debug support.

MIKROELEKTRONIKA, www.mikroe.com/sibrain-for-gd32vf103vbt6